Towards Effective Public-Private Partnerships in Research and Innovation: A Perspective for African Research Granting Councils

Oyelaran-Oyeyinka, Banji[a], Vallejo, Bertha[b] and Vasudev, Shruti[c]

[a] 814, Eluid Mathu, Runda, Nairobi, Kenya
[b] Tilburg University, the Netherlands and UNU-MERIT, the Netherlands
[c] European School of Management and Technology (ESMT), Berlin, Germany

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1 Introduction

Contemporary scholarship calls for a variety of partnerships within and outside national borders aimed at optimizing collaborative research outcomes. This paper presents the findings of a study on the policies and practices for engaging in public-private partnerships (PPPs) in research and innovation (R&I) in different countries in sub-Saharan Africa (SSA). The study found that partnerships, no matter their nature, co-evolve with the prevailing institutional environment and that changes in extant knowledge structures tend to be slow and gradual. The policies and practices in relation to partnerships are shaped to a large extent by the respective country's historic development (Bartholomew, 1997, p. 244). Policies and practices, as well as the institutional behavior and collaborative patterns of actors, are also shaped by socio-economic factors, which tend to be rooted in society over time. PPPs in R&I have become a key element in the mix of tools deployed in the research and innovation policies of many countries around the world. Although this instrument dates back to the 1980s, in recent years there has been renewed interest in, and discourse about, PPPs in R&I, which have found their way back into policy discussions, not only in Europe and the United States of America (USA), but also in many developing countries, particularly in Africa.

The idea of PPPs in R&I is by nature a systemic one. Operationalizing the concept necessarily involves several system actors and impacts on the productive engines of nations, such as industries and firms. This tool is regarded as a mechanism for addressing market failures and coordinating complex activities involving a diverse set of actors including national science system actors, such as universities and research centres. Its functional domain encompasses a broad array of elements, including intellectual property issues relating to research, technology and knowledge generation. Accordingly, in this study we examine PPPs in R&I from an innovation systems perspective, taking into account the diversity of actors that shape the enabling environment, the contracts that bind the engagements, and the different forms the interactions take.

The paper opens with the methodology and background, followed by the theoretical framework for understanding the surge of these new PPPs in R&I. It then sets out the analytical framework before providing a general overview of PPPs in R&I in different parts of the world, focusing on lessons learnt for the SSA context. Different case studies are examined, supplemented by secondary sources, with the aim of establishing the typologies of PPPs in R&I to guide interventions in SSA.

The research is triangulated using semi-structured interviews with stakeholders of PPPs in R&I in different European and SSA locations in an effort to identify how they are established and common practices and experiences in their relation to their operation. The paper seeks to provide practical lessons for science granting councils (SGCs) and practitioners working in this area, particularly those working in the African context.

2 Methodology

This research is based on an extensive literature review on the evolution of ST&I policies and innovation policies and the theoretical frameworks influencing this evolution. We draw from the literature on innovation systems, interactive learning and capability building to construct a conceptualization that enables us to understand the implementation of PPPs in R&I in different settings.

The study is designed to understand PPPs in R&I in SSA countries that are part of the Science Granting Councils Initiative, namely Botswana, Burkina-Faso, Cameroon, Cote d'Ivoire, Ethiopia, Ghana, Kenya, Malawi, Mozambique, Namibia, Rwanda, Senegal, Tanzania, Uganda, Zambia and Zimbabwe. We also include perspectives from Nigeria and South Africa as points of comparison.

An extensive desk review of secondary case studies in which PPPs in R&I were implemented in the different countries was conducted and, where possible, the authors of these studies were contacted for details that could enrich our research. In the course of the desk research, we identified several key reports on PPPs in R&I under the Science Granting Councils Initiative. We scheduled interviews with the corresponding authors with aim of including their reflections in the research (Joanna Chataway et al., 2017; Mouton, Gaillard, & van Lill, 2014; Ssebuwufu, Ludwick, & Beland, 2012). Case studies beyond SSA were also analyzed to understand the best practices for implementing PPPs in R&I outside our sample.

In addition to an extensive literature review, we solicited input, through an online survey questionnaire, from informants and experts familiar with the workings of SGCs, as well as agencies with similar missions, such as national science councils and national commissions for science and technology, to enrich the research. Within this group were individuals who contributed to the first envisioned comprehensive and in-depth study detailing the functioning and roles of SCGs or equivalent bodies in SSA during a consultative workshop in South Africa in November 2013 (Mouton et al., 2014). We also sent survey questionnaires to a total of 43 individuals across 33 organizations and 18 countries, including individuals in 16 member organizations of SGCs in Africa.

As the response rate to the survey questionnaire was very low (under 10%), we scheduled Skype and phone interviews with key actors from SSA countries. We interviewed several directors of technology transfer offices, university-industry linkage and technology offices at main universities in our SSA sample countries, and directors of industry associations. This helped us to understand the current practices around PPPs and the respondents' personal impressions of these practices (based on their experience). In addition, we conducted three key interviews with policy advisors of international organizations (e.g., NWO, IDRC and DFG), who gave us a general perspective on the role that PPPs in R&I play in both policy planning and market implementation. This made us aware of the different levels of readiness to engage in PPS in R&I around the world, which implies different levels of complexity in the partnerships R&I implemented.

3 Background

3.1 Science, technology and innovation and PPPs in Africa

The centrality of S&T as a driver of economic growth and development has long been recognized in academic and policy literature. Studies have shown how S&T enhances a country's industrial competitiveness and increases the efficiency of production routines and systems (J. Chataway et al., 2009; NACETEM, 2010; NEPAD, 2006). As early as the 1980s, Nelson and Winter (1982) identified technological change and innovation as drivers of national competitiveness.

According to several regional declarations, African countries are committed to development led by science, technology and innovation (ST&I). This is evidenced by the adoption of the 10-year Science, Technology, and Innovation Strategy for Africa 2024 (STISA 2024) in June 2014 at the 23rd Ordinary Session of African Union Heads of State and Government Summit. STISA 2024 is aimed at accelerating and developing human capital, innovation, industrialization, entrepreneurship and value addition to facilitate social transformation and enhance the economic development and, thus, competitiveness of the continent (African Union, 2014). Currently, over two-thirds of African countries have ST&I policies and strategies (The African Capacity Building Foundation, 2017), and the last decade has seen an increase in research fund commitments from national governments, the emergence of new organizations funding STI, and increased rates of scientific production, innovation activities, and cross-regional research collaboration (African Technology Policy Studies Network (ATPS) & The Scinnovent Centre, 2017).

Many African countries, however, lack the requisite capacity to optimize the potential of ST&I to enhance the structural transformation of their economies. The majority have "underdeveloped STI institutions and fail to effectively generate and deploy knowledge and technological innovations for socioeconomic growth" (The African Capacity Building Foundation, 2017, p. viii). As an exception, countries, like South Africa and Nigeria, have relatively well established policy and scientific institutions, such as ministries for science and technology, national research foundations, the technology innovation agencies, and various innovation hubs and portals. There are other countries where knowledge generation and management systems are not as well developed and the ministries of economy, industry and higher education carry out the ST&I mandate alone. For example, average financing for research and development (R&D) in African countries is about 0.5% of GDP, which is less than the target of 1% of GDP (The African Capacity Building Foundation, 2017). Table 1 and Table 2 present the different investments in R&D carried out by members and non-members of the Science Granting Councils Initiative.

Table 1. R&D expenditure by Science Granting Councils Initiative member countries as a percentage of GDP

Country	Year of Latest Available Data	Research and development expenditure (% of GDP)
Burkina Faso	2009	0.20015
Botzwana	2013	0.5423
Cote D'Ivoire	n/a	n/a
Ghana	2010	0.37655
Ethiopia	2013	0.60468
Kenya	2010	0.7856
Malawi	n/a	n/a
Mozambique	2015	0.33732
Namibia	2014	0.33695
Nigeria	2007	0.21939
Rwanda	n/a	n/a
Senegal	2010	0.5413
Tanzania	2013	0.52889
Uganda	2010	0.47505
Zimbabwe	n/a	n/a

Source: United Nations Educational, Scientific, and Cultural Organization's (UNESCO's) Institute for Statistics and https://data.worldbank.org/indicator/GB.XPD.RSDV.GD.ZS?end=2015&start=2015&view=map&year_high_desc=false

Table 2. R&D expenditure by non-Science Granting Councils Initiative member countries as a percentage of GDP

Country	Year of Latest Available Data	Research and development expenditure (% of GDP)
China	2015	2.06558
India	2015	0.6274
Russia	2015	1.13202
S. Korea	2015	4.22816
Germany	2015	2.87749
Canada	2014	1.61548
Italy	2015	1.33488
USA	2015	2.79385
UK	2015	1.70304
France	2015	2.23135
Japan	2015	3.28363

Source: Elaborated by the authors with information from UNESCO's Institute for Statistics and https://data.worldbank.org/indicator/GB.XPD.RSDV.GD.ZS?end=2015&start=2015&view=map&year_high_desc=false

Alongside recognition of the need for ST&I in order to achieve sustainable growth and development, global leaders are increasingly articulating the need to form PPPs in order to achieve ST&I goals. African governments, have reiterated the role of PPPs and the desire to strengthen collaborations with public and private sector partners through various policy initiatives and forums, including the New Partnership for Africa's Development agenda (NEPAD, 2013) and the Second Ministerial Forum on Science, Technology, and Innovation in Rabat on 17 October 2014. The Sustainable Development Goals, which were collectively agreed upon, have also placed PPPs as central to achieving inclusive and sustainable growth.

3.2 Science granting councils and the Science Granting Councils Initiative

The key players promoting PPPs around R&I within a country's national system of innovation are the SGCs. The role of SGCs and their proxies in different settings is largely to provide support that funds science through a diversity of platforms. However, they are also taking on functions such as valorization, dissemination and the promotion of scientific findings, as well as data management and policy advice.[1] Importantly, these councils act as agents of the government while representing the interests of the country's scientific community. They are important "'intermediaries' in the flow of international funding and technical support to R&D performing institutions in a country" (Mouton et al., 2014).

A host of countries in SSA have long-established SGCs; however, while their broad mandate is to advocate, fund and support ST&I, they have different national structures and, therefore, operate in different ways, with implications for how they are funded and how they carry out their functions. National SGCs differ in their history, setup, level of organization, presence within national systems of innovation, and fostering of PPPs in R&I. A 2017 study by the Science Policy Research Unit and the African Centre for Technology Studies that looked at how political economy factors influence the evolution of science funding in SSA provides two instructive findings for this paper (Joanna Chataway et al., 2017). Firstly, all five case study countries (Ethiopia, Kenya, Rwanda, Senegal and Tanzania) were committed to increasing funding, but, in general, funding levels were still low (Joanna Chataway et al., 2017). In these countries, SGCs have been established, but in varying ways, which has implications for how they are funded and carry out

[1] Bolo, Odongo, and Awino (2016) provides an interesting analysis of scientific R&D funding in Kenya (with emphasis on health R&D financing). Their research presents the role played by NACOSTI, which provides funding through competitive ST&I grants.

their functions). Secondly, while there is reference to the role that the private sector can play at both the regional and national levels, private sector funding remains low, and engagement 'patchy' across the case study countries (Joanna Chataway et al., 2017). The authors point out the following:

> *Greater involvement from the private sector will take dedicated effort and there is a need for greater communication between private and public sectors about the value of different types of research. Greater consideration could be given to the variety of ways in which the private sector could be encouraged to fund and engage with public sector and joint funding initiatives. The majority of firms will not make use of formal R&D activities and may not identify as innovating companies. The type of engagement and activity will also vary across sectors. However, there will be aspects of research that may have relevance and use and although actual private sector spend may remain limited, greater involvement will lay the basis for sustained and growing collaboration.* (Joanna Chataway et al., 2017, p. 43)

As the numbers of SGCs in Africa grow and their potential to strengthen PPPs for scientific research and innovation increases, it is important to enable discussions about PPPs for R&I, their design, management and impact, in order to shape the roles of such partnerships within national systems of innovation (African Technology Policy Studies Network (ATPS) & The Scinnovent Centre, 2017). Accordingly, the Science Granting Councils Initiative commissioned this report to facilitate this discussion. The Science Granting Councils Initiative in SSA is a five-year initiative, jointly funded by the United Kingdom's Department for International Development (DFID), Canada's International Development Research Centre (IDRC) and South Africa's National Research Foundation. The initiative works to strengthen the capacity of SGCs in SSA to support research and evidence-based policies that will contribute to economic and social development. The objectives of the Science Granting Councils Initiative include strengthening the ability of science granting councils to: (i) manage research; (ii) design and monitor research programmes based on the use of robust ST&I indicators; (iii) support knowledge exchange with the private sector; and (iv) establish partnerships between councils and other science system actors (African Technology Policy Studies Network (ATPS) & The Scinnovent Centre, 2017).

3.3 Key questions addressed in this paper

In order to enhance the role of PPPs in socio-economic development and in support of the STISA 2024, the Science Granting Councils Initiative commissioned this paper to explore issues related to PPPs in research and innovation and to propose good practices from around the world (African Technology Policy Studies Network (ATPS) & The Scinnovent Centre, 2017). In particular, the paper addresses the following key questions:

- What are the key characteristics of PPPs in R&I in the SSA context?
- How have PPPs in R&I contributed to the translation of research outputs into new products and services?
- What are the current challenges in achieving strong PPPs in R&I in SSA?
- What are the existing good practices of effective PPPs in R&I in SSA and around the world?
- What policies, practices and incentive structures are required in order to strengthen PPPs in R&I?
- What changes (for example, structural and institutional or to roles and mandates) should be made to enhance the capacity of science granting councils to catalyze, facilitate and mediate PPPs in R&I?
- What analytical framework, including performance measures and indicators, might be used by science granting councils to assess the impacts of their PPPs in R&I programmes?

The research results of this study were presented at the Annual Forum, convened by the Science Granting Councils Initiative in partnership with the African Union Commission and the New Partnership for Africa's Development. The forum hosted various African science granting councils and key stakeholders and provided a platform for the preliminary findings from this study to be discussed and refined.

4 Theoretical framework

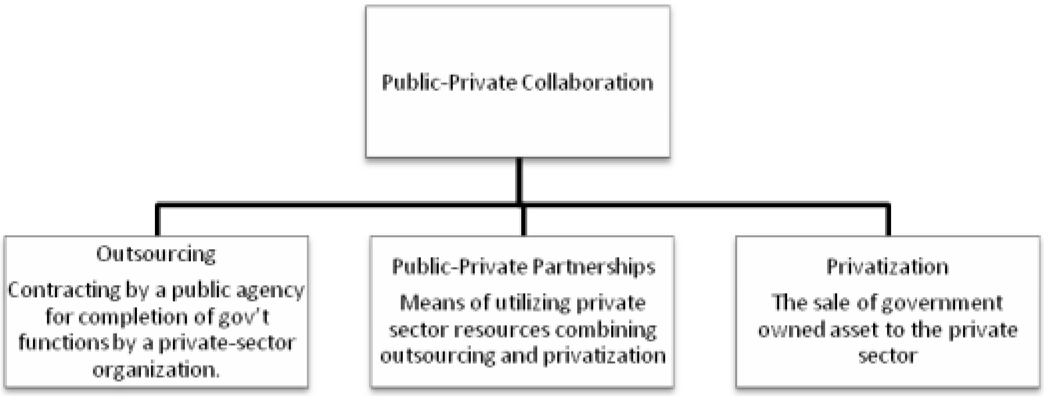
4.1 Partnerships and collaborations

Defined broadly, a partnership involves elements of collaboration contracted through an agreement. In this paper, we conceptualize and elaborate PPPs in R&I within the structure and dynamics of network collaborations among a diverse set of actors. We do this within an innovation systems framework that includes agents in the public and private sectors, be they firms, universities, public research institutions or funding agents. The importance of systemic actions and coordination is now well established (Edquist, 1997). It is also widely accepted that innovation actors are ordinarily embedded in networks of varying densities depending on the development support environment. An understanding of these kinds of important organizational forms not only points markets in the best direction for investment, it directs state action and policy to the best forms of intervention to attenuate market failures. At the micro-level, an understanding of partnership networks helps the policy process in the structuring of linkages among economic and non-economic agents, such as firms, in a way that results in consistence patterning of persistent interaction. This makes partnership networks more than mere channels of information exchange, but institutions of knowledge creation, because the persistence of relations suggests structure and relative stability. Evidently, research partnerships are included in this categorization.

Partnerships for innovation include activities such as joint ventures, research corporations, joint R&D, technology research agreements (such as technology sharing, cross-licensing and mutual second-sourcing), direct investment, customer-supplier relations and R&D contracts, among other things. While collaborations are mainly sealed by contractual agreement, innovation networks may also be based on informal collaboration involving knowledge exchange by individuals embedded in different organizations. In sum, a PPP in R&I is constructed largely to foster innovation; however, it is part of a much wider and broader set of collaborative relationships, which can be formal or informal (Hagedoorn, Link, & Vonortas, 2000).

The literature identifies three types of public-private collaboration: namely, outsourcing, PPPs, and privatization. Figure 1 illustrates the differences between these concepts.

Figure 1. Types of public-private collaborations



The European Commission's Guidelines for Successful Public Private Partnerships (2003) indicate that PPPs can be classified according to how responsibility is shared in procurement; namely: (i) traditional public sector procurement; (ii) build-operate-transfer (BOT), (iii) design-build-finance-operated (DBFO); and (iv) build-own-operate (BOO), where the first one implies major public responsibility and the last one more extensive private responsibility (European Commission, 2003). These partnerships are distinguished by their different contractual arrangements (e.g., such as service contracts, management contracts, leases, build-operate-transfer arrangements and concessions) (European Commission, 2003). The type of arrangement adopted depends on the type of project, the needs being addressed and the sector of implementation.

4.2 Public-private collaborations

Collaborations or associations between the public and the private sector on infrastructure and development issues can be traced back as far as the 18th century (Nirupama, 2009). However, in the mid-1970s, the adoption of these schemes became more commonly used by the public sector seeking to promote the development of road infrastructure, as well as health, prisons, water and sanitation services, etc. In this context, public-private collaborations complemented the limited public budget with alternative sources of (private) capital, external knowledge and skills, and risk sharing. By the late 1980s, Europe, Australia and the USA had already adopted public-private collaborations and agreements as common practice in the financing of development projects. Since then, PPPs have been recognized as an innovative mechanism by which to fund projects at a reduced cost, create jobs, improve delivery, and increase the quality of performance. Due to limited state resources, the evidence suggests that PPPs have become an important tool for the public sector in the delivery of basic goods and services, as they allow for leveraging experience and financial funds from the private sector. By the late 1990s, PPPs emerged as an instrument of new public management, becoming a preferred approach for the public sector and an instrument that enabled governments to leverage their financial resources and offer the public a better return on investment (US National Council of PPP, 2008).

Koschatzky (2013), as cited in Koschatzky (2017), defines PPPs as "a public service and/or private activity, which is jointly financed and operated by the public sector and industry on the basis of a contract which regulates financing and operation" (Kroschatzky, 2013, pp. 21-22). PPPs are, therefore, understood as those alliances in which the public and the private sector enter into long-term collaboration to produce better quality products at a lower cost.[2] They provide a mechanism for leveraging not only skills, but, more importantly, finance from the private sector to procure public infrastructure and services (Grimsey & Lewis, 2007a, 2007b).

4.3 Different types of PPPs

PPPs operate under a mid- or long-term contractual arrangement between the public and the private sector with the objective of maximizing the use of the best skills and capabilities of each sector (Agyemang, 2011). As a generalization, the recent types of PPPs can be characterized as follows: (i) PPPs in which the cooperation among partners that is long-term and stable; (ii) PPPs in which the contributions of each partner (public and private) are clearly established under formal

[2] https://www.government.nl/topics/public-private-partnership-ppp-in-central-government.

arrangements; (iii) PPPs in which the outcomes and performances are clearly defined; (iv) PPPs in which the definition of aims and objectives, as well as the monitoring and evaluation activities, are mostly conducted by the public partner; (v) PPPs in which the public partner holds the role of organizer, regulator and controller, while the private partner holds the role of direct operator; and (vi) PPPs in which the risks are mostly transferred to the public partner (Reillon, 2017b).

Although PPPs have been traditionally linked to the development of infrastructure, the health sector and the water sector (i.e., supply partnerships), their adoption in the last decade has expanded to many other economic sectors. Table 3 presents different types of PPPs.

Table 3. Types of PPPs

Type of PPP	Reason for formation	Challenges
Supply partnership	Optimization of the use of available knowledge and resources	Central entity must be a neutral and trusted party
	Promotion of economic growth through a more competitive private sector	Intellectual property structure
	Promotion of 'open innovation'	Performance measurement
	To address topics that require a neutral/multi-stakeholder environment	
Product development partnership	Risk sharing	Engagement of small and medium-sized enterprises (SMEs) and large companies
Research partnership supporting early stage innovation	Increased scale	Time-lines and sustainability
Partnership for concept development and overall systems strategy	Focus on R&D priorities/definition of research strategy	Consortium leadership and project management
Source: World Health Organization (2013)		

4.4 Research partnerships

Research partnerships are those innovation-based partnerships involving significant and explicit R&D efforts (Hagedoorn et al., 2000). This form of partnership devotes itself to the R&D of new products, processes and services. It usually has a limited number of partners who pull funds together to pay for specific R&D. The reward of this kind of partnership is that actors in the arrangement are entitled to a proportion of the income derived from the investment.[3] From the literature, we know that research collaboration has been practiced for as long as modern science itself. Hagedoorn et al. (2000) define a research partnership as "an innovation-based relationship that involves, at least partly, a significant effort in R&D" (pp. 567-568).

Authors such as Okamura et al. (2003) employ the term 'innovation networks' to describe collaborative relationships created between business and non-business entities. Spatially, these

[3] https://www.powerlinx.com/blog/rd-partnerships/

relationships may involve North-North, North-South and South-South collaborations and could equally expand across traditional and non-traditional sectors, involving both knowledge centres and industries. According to Hagedoorn et al. (2000), research partnerships are made up of the members in the relationship (i.e., the partners) and the organizational structure of the relationship (i.e., informal or formal arrangements and its different modalities). Partners in the network could be universities, research centres, government agencies and/or private firms.

The literature explains the motivation of firms to enter into research partnerships from the perspective of transaction cost economics, strategic management and industrial organization, innovation theories, and economic geography (Hagedoorn et al., 2000; Koschatzky, 2017). The model implemented under this scheme is highly attractive to entrepreneurial academics because it allows them to acquire further leadership skills and leverage capabilities extant in the network. Research partnerships have gained considerable attention as a S&T policy tool aimed at promoting domestic technology and knowledge transfer. The traditional science policy model up until the 1970s was focused on the promotion of cross-national technology transfer, mostly from the North towards countries in the South (Bozeman, 2000), creating technological dependency discussed by the import substitution theories. In the late 1970s, the S&T policy agenda shifted towards technology transfer within nations. This notion took the form of formal research contracts, shifting the focus toward the researches' pre-market application or implementation, which was traditionally addressed by the private sector. The main policy objective of this strategy was to deploy financial incentives and public funding for the purpose of turning research into products, processes and services in order to promote economic and social progress (Wright et al 2008).

In an advanced industrial economy like the USA, the objective is, in part, to gain technological leadership by improving technology-driven competitiveness. To achieve this aim the US government has invested considerably in the establishment of institutional structures to facilitate technology transfer between universities and industries (Bozeman, 2000; Sampat & Nelson, 2000). One such institution is the Industry-University Cooperative Research Center, established in the 1980s. This strand of the S&T policy aims to promote long-term partnerships among industry, academia and the government. This programme holds out the possibility of a low threshold for industrial players to engage with other system actors (such as universities and research institutes) and, eventually, can provide significant payoffs in terms of long-term benefits and profit.

Within the EU, countries promoted research partnerships in the 1980s with the adoption of the first Framework Programmes (FP). These FPs are policy tools that foster research coordination across the EU, but, more importantly, they are financial tools that support the competitive capacity of the member states (Reillon, 2017a). Through the FPs, the public research organization structures of the EU are modernizing, avoiding duplication and limiting intra-community competition. After the first FPs (FP1 in 1983, FP2 in 1987, and FP3 in 1990), they were adapted to the needs of the European Commission and, in the Maastricht Treaty in 1993, the legal framework was formulated to transform FPs into financial tools for research activities. In FP4 (1994) and FP5 (1998), the topics for research were broadened[4] and the frameworks started to display an emphasis on pre-competitive research.[5]

Despite differences in approaches, the common elements in the S&T strategies were the creation of policies influencing collaborative pre-competitive research, particularly in information technology and other key sectors; the creation of new technology-based firms; and a constant emphasis on stimulating the integration of medium and small-sized enterprises (SMEs) (Rothwell & Dodgson, 1992). In the South as a regional block, the literature on the latecomer firms identifies several case studies, especially from the 1990s, of firms updating their capabilities, not only through informal arrangements, but through formal contractual arrangements, such as research joint ventures (Bray & Link, 2017), cross-licensing, research agreements, direct investment, customer-supplier relationships, R&D contracts, licensing and outsourcing, among other type of research partnerships. Drawing on an earlier study of African systems, it was observed:

> *Generally, the picture of S&T capacity building in Africa is one of a weak but growing supply of technologies and human resources and strikingly, a low demand and therefore limited or even unproductive deployment of these resources. By and large, the literature indicates that partnerships for S&T capacity building have made only a modest contribution to the development challenge in Africa and largely not succeeded in resolving old and new problems such as low agricultural productivity, weak technological capabilities in manufacturing and processing, poverty, food security, environmental degradation and many others* (Oyelaran-Oyeyinka, 2005).

For most African countries, this situation has changed only marginally. The key constraints of their underdeveloped environment limit how far advanced society models can be adopted by these countries (Oyelaran-Oyeyinka, 2006). To start with, a large part of knowledge in African societies is tacit in nature; African societies thrive on oral history, whereby much of the techniques of local knowledge production are passed on from master craftsmen to apprentice. Even if this is hardly acknowledged in official documentation, much of the learning takes place through informal institutions and, for much of Africa's history, knowledge of nature was regarded as a secrets to be

[4] ICT, industrial technologies, environment, life sciences, agriculture and fisheries, life sciences, non-nuclear energy and transport.
[5] Details on the structure of the EU FP can be found in Reillon (2017a).

passed on to the 'chosen', most often a person's offspring (Oyelaran-Oyeyinka, 2006). Second, institutions for the codification of knowledge were barely developed, but 'modern' organizations for doing this are embedded in many widely-accepted social systems and practices (Oyelaran-Oyeyinka, 2006). Thirdly, orthodox measurements of the generation and flow of knowledge concentrate largely on measurable data such as patents, scientific publications and R&D statistics (Oyelaran-Oyeyinka, 2006). These practices are supported by institutions of knowledge creation, such as networks of scientific laboratories and patent offices, and practices such as standards and metrology. For example, the National Institute of Standards and Technology (NIST) had a budget of USD 964 million in 2016. NIST promotes US innovation and industrial competitiveness by advancing the measurement of standards and technology in ways that enhance economic growth. Most African countries lack such supporting institutions, and even though they have adopted policies of advanced nations, policy makers and scholars tend to underrate and poorly rank informal networks, which in some countries contain a vast knowledge base that is largely tacit.

4.5 Public-private partnerships in research and innovation

Beginning in the 2000s and induced mainly by the global economic crisis, science and technology policies started moving towards today's innovation policies by adapting research from links between science centres and industry towards partnerships focusing on research application or implementation, as well as aiming to address market failures. The Organization for Economic Co-operation and Development (OECD, (2014) initiated this type of PPPs, which it coded as 'strategic PPPs'. These strategic PPPs evolved into what the EU later classified as PPPs in R&I, which are top-down-oriented PPPs characterized by long-term public support addressing strategic issues, with the following aims: (i) to strengthen the industrial base; (ii) to resolve long-standing global problems; (iii) to support economic growth; (iv) to create employment; and (v) to provide leadership at the technological frontier and foster technological comparative advantage.

PPPs in R&I are defined as modes of cooperation between publicly-funded research organizations and private firms, characterized by a long-term institutional and strategic formal arrangement in order to achieve complementary goals by jointly operating research activities (Buckland, 2009), jointly sharing financial risk, and jointly exploiting research results (Becker & Dietz, 2004). Features of successful PPPs in R&I identified in the literature are: (i) geographic and social proximity; (ii) medium to long-term collaboration arrangements; and (iii) a legally-regulated PPP contractual agreement (Koschatzky, 2017; Koschatzky et al., 2015).

(a) Spatial and social proximity

For the European PPPs in R&I, spatial proximity is a mandatory requirement. Proximity among partners in a collaborative network is significant, particularly during the early phases of cooperation and research. Employees from the private sector are in constant communication (although not on a daily basis) with the research staff of the universities or research centres. Proximity promotes interactivity, as was also found in the African context, where it is undeniably a significant factor due largely to the problematic state of knowledge and physical infrastructure in African countries. The proximity of firms to one another, as well as with organizations providing technical services, was found to be an important determinant of innovation success and firm performance by much of the research in developing countries (Oyelaran-Oyeyinka, Adelaja, & Abiola, 2014). Collaborative opportunities, technical efficiency and higher productivity were found where proximity fosters collaboration among firms. Where networks are characterized by geographic proximity, interactive collaborations promote learning and contribute in significant measure to building technological capability in firms (Lundvall, 1988, 1995; Oyelaran-Oyeyinka, 2004b). The research found that firm-to-firm collaboration with clients, contractors, suppliers and input suppliers tends to be the most widespread among small enterprises in close proximity, especially industrial clusters (Oyelaran-Oyeyinka, 2004b). Relationships with input suppliers as well as domestic machinery suppliers and maintenance organizations are the most prominent. Small producers tend not to patronize universities and research centres, due to 'relational distance', manifested in the ivory tower mind set of many research entities. Firms are far more concerned with meeting daily production schedules and much less engaged in medium to long-term innovation planning.

(b) Length of the contractual agreement

A medium or along-term formal arrangement is important in research, particularly research that involves collaboration between academia and industry.

(c) Legally-regulated agreements

Country characteristics such as a weak institutional frameworks, a high level of corruption and weak rule of law can create conflict between private and public parties regarding things such as revenue and intellectual property rights, especially as projects advance and start producing outputs. Legally-regulated agreements help reduce the potential for such conflicts.

A very important aspect of PPPs in R&I is the legal regulation of intellectual property rights and informal knowledge flow issues (Koschatzky, 2017). The regulation of intellectual property rights under PPPs in R&I remains an important challenge around the globe. Case studies in Europe, Australia and the USA indicate that although intellectual property rights are discussed during the preparatory phases of the different projects, the different internal structures and requirements of the partners can lead to different arrangements (Koschatzky et al., 2015). In most cases there are no strict rules or guidelines for the regulation of intellectual property rights; therefore, they are negotiated among all the partnership actors (including aspects such as the allocation of intellectual property and the income from intellectual property). As intellectual property management is heavily context specific, in most cases, the responsibility rests with the organization that has the greatest capacity to administrate it.

Miranda Sarmento and Renneboog (2017) present evidence of opportunistic bidding for PPP contracts, which once they are acquired – and the competition eliminated – lead to renegotiation to increase revenue. Their analysis shows that incomplete legal contracts (due to contract complexity, size and length), favor renegotiations at the operational stage. Election years (generally the year before an election) are positively correlated with the renegotiation of large PPPs, either by governments or the private sector (Miranda Sarmento & Renneboog, 2017).

5 Analytical framework

5.1 The systems perspective and PPPs in R&I

In this paper, we have adopted the systems of innovation framework for analysis of the research results, because it best describes the activities of actors in a PPP. The systems of innovation concept rests on a number of conceptual platforms and articulates the generally agreed notion that firms, universities and economic agents do not innovate in isolation. For this reason, 'learning organizations' have to develop modes of interaction with other agents within a boundary – national, regional or sectoral – that marks their system of innovation.

The system of innovation is defined as "the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies" (Freeman, 1987, p. 1). Lundvall's concept of national systems of innovation emphasizes the diffusion of "economically useful knowledge" (Lundvall, 1992, p. 12). There are a wide variety of definitions (Nelson and Rosenberg, 1993; Metcalfe, 1994), but there is also a fairly good convergence of the key ideas at the heart of the systems of innovation framework. One of these ideas is the persistent, but uneven, distribution of the capabilities of firms to innovate across sectors, countries and regions. This skewed effect of innovation performance is a function of specific national or sectoral factors and, as such, the competitive advantage of sectors and nations depends greatly on how advanced their system of innovation is and how well it has generated coherence and interactions.

Following the earlier path-breaking work of Freeman (1987), Lundvall (1992), Nelson (1987) and Edquist (1997), scholars have made progress in applying the systems of innovation concept to developing countries (Arocena & Sutz, 1999; Cimoli, 2000; Gu, 1999; Oyelaran-Oyeyinka & Adebowale, 2012). These sources point out not only the considerable differences between advanced industrial countries and developing countries as a bloc, but also the marked differences between individual countries within these blocs. The systems of innovation in developed and industrialized countries differ in several ways from those in developing countries, and specifically in three respects. First, advanced economies tend to be highly science-intensive and technology-intensive, with relatively high levels of domestic investment in R&D. Second, industry and the service sectors are far more advanced and complex and also far more knowledge-based and innovation-driven in rich industrial nations. Third, and complementary to the first two, advanced economies have high levels of skilled manpower, the importance of which is accentuated by intensifying global competition. To be sure, PPPs in R&I are embedded in these contextual conditions.

PPPs in R&I foster innovation, which in turn grows out of a network of private and public sector actors whose interactions produce, diffuse and use knowledge that is economically useful (Lundvall 1992). Additionally, a system is made up of key actors (components) and is driven by interactions that define their engagement. Continuous interaction is critical because of the nature of organizational behavior – they do not innovate alone. The system is dynamic and evolving, and complex relationships get reconfigured. The framework places emphasis on interactive learning between producers, suppliers, buyers and the organizations that support them (Mytelka, 2006). It acknowledges the influence of routines and historical habits, as well as the importance of the local and international policy environment, which sets the parameters within which all these actors learn and innovate (Lundvall, 1992; Nelson, 1993; Nelson & Winter, 1982). Habits and practices influence innovative behavior and may inhibit efforts to diffuse and use knowledge. The approach, thus, recognizes the influence of actors and markets, including networks of firms and farmers, knowledge generation and training institutions such as agricultural research institutes and training centres, and financial institutions. Policy – specifically technology policy – and the macro-economic climate make a considerable difference.

In sum, the innovation system concept is useful for our understanding of PPPs in R&I, because it provides a framework for: (i) exploring patterns of partnerships; (ii) revealing and managing the institutional context that governs these relationships and processes; (iii) understanding research and innovation as a social process of learning; and (iv) thinking about capacity development in a systems sense (Hall, 2002). Therefore, in applying the concepts underpinning successful PPPs in advanced and developing countries in Africa, we need to call attention to the idiosyncratic contexts distinguishing the two environments. For example, when a developing country in Africa attempts to replicates an institutional form such as a PPP in R&I, its success cannot be presumed without major attention being paid to the prevailing objective conditions of an underserved knowledge economy. For example, in the African setting, support institutions are weak and some critical ones do not exist; as such, new institutions may have to be built from scratch, unlike in countries where such institutions have existed for decades. In addition, support institutions, actor capabilities and the macroeconomic environment all differ. It should be expected that developing institutional forms in African counties capable of the same level of PPP and of research effectiveness as their counterparts in advanced nation will require continuous learning and experimentation.

5.2 How institutions shape systems of innovation

The point made above concerning the marked differences in productivity in the innovation systems of countries at different levels of development can be largely explained by the capability differences of their institutions (North, 1996).[6] We apply the definition of an institution proposed by North (1996), as follows:

> *…the rules of the game of a society or more formally the humanly devised constraints that structure human interaction. They consist of formal rules (statute law, common law and regulations); and informal constraints (social norms, habits, routines and practices) and the enforcement characteristics of both.*

In a narrow sense, institutions are conceived as organizations such as universities and technology institutes, while in broad terms institutions include the political context, habits, practices and norms, and the rules regulating relations and interactions between people. Lundvall's (1992, p. 12) conceptualization of the concept of a national system of innovation emphasizes the diffusion of "economically useful knowledge".

The African context of underdevelopment is very different and displays distinct system and institutional characteristics that differ, in some cases profoundly, from those found in advanced economic countries. The growth of knowledge takes place through long processes of

[6] Edquist (2001) identifies nine broad similarities, namely: all SI approaches place innovation at the centre of activities; innovation processes are evolutionary in nature; all reject the concept of optimality and emphasize diversity and variety; they take innovation as an interactive learning process; they stress the interdependence between organisational actors; and they affirm that innovation generally occurs within an institutional context..

learning, while information reproduction is carried out by duplication. PPPs in R&I tend to evolve, in part because knowledge is costly, as learning is a complex process that can be formal or informal and may be tacit or difficult to replicate and process. R&D is only one component of technological knowledge, and the growth of knowledge is related to the growth of the economy. As such, the extent to which PPPs in R&I will succeed is to a large extent associated closely with the conditions of Africa's late development (Oyelaran-Oyeyinka, 2010, p. 70).

Systems of innovation differ equally and significantly under the two sets of development conditions. Clearly, countries have evolved different knowledge bases; for example, because African nations started much later and evolved much more slowly than East Asia, for example, the R&D and innovative capacities are decades apart. For instance, Nelson noted the differences that size makes in systems of innovation shaped by political and historical environments: "The differences in the innovation systems reflect differences in economic and political circumstances and priorities [while] size and the degree of influence matter a lot (Nelson, 1993, p. 507)." By implication, there are external conditions shaping the domain of R&D and the institutions that evolve to shape PPPs in R&I, for example. In the context of this discourse, we identify four broad dimensions to guide our framing of good practices for PPPs in R&I (Oyelaran-Oyeyinka & Adebowale, 2012). First, in developing countries, the amount of R&D[7] (an important source of learning for innovation) carried out in universities and firms is significantly lower than in advanced industrial countries. In addition, large amounts of innovative activities in firms are adaptive and imitative and product-based rather than process-centred. Significantly, the transactional nature and functions of PPPs in R&I are very different, and the gap in the overall gross domestic product (GDP) even more so. For instance, the whole architecture of industrial production in advanced nations is geared to supporting and promoting R&D-intensive hi-tech products. Examined closely for example, the US system is more specialized in significant respects than that of the EU; public-sector research, for example at universities, is more closely linked to industry, performing R&D functions that private-sector firms fulfil in Japan, for instance (Edquist and Texier, 1996).

Second, while African universities and specialized training centres were established post-independence for the express purpose of building research and industrial manpower, most have failed in this mission for a number of reasons (Oyelaran-Oyeyinka, 2004a). While these organizations exhibit a semblance of performance, especially the production of university graduates, they struggle to meet minimum global standards of good performance. And, for the

[7] R&D, however it is defined, is not only an avenue for economic and social diversification (new products and processes), but also helps build scientific and technical competencies.

most part, African countries have failed to meet the challenges of the new, more competitive global economy (Oyelaran-Oyeyinka and Barclay, 2003).

Examined in a comparative global perspective, the situation for Africa's system actors, such as universities is also very different. Being a top university in Africa, for instance, does not translate to anything even close to being a top university globally. In 2016, the University of Cape Town was the best performer in Africa, but 148th in the Times Higher Education World rankings, and University of Witwatersrand was second in Africa, but 182nd globally.

The latest world rankings (2018) place South Africa's University of Cape Town in 171st position globally, down 23 positions, although it still remained top in Africa for the same year. The University of Witwatersrand, which remains second in Africa, is now placed lower than 250th in the rankings. These rankings suggest a clear worsening, in relative terms, of the state of African universities over the past two years.

Furthermore, African universities have also not been at the top globally in attracting industry funding. The Times Higher Education 2015–2016 private sector investment per academic ranking had only one African university – Stellenbosch University – in the top 20 (ranked 15). The University had USD 156,600 in industry income per academic. The top five universities in terms of industry income per academic were: (1) LMU Munich, Germany (USD 392,800), (2) Duke University, USA (USD 287,100), (3) Korea Advanced Institute of Science and Technology, South Korea (USD 254,700), (4) Johns Hopkins University, USA (USD 249,900), and (5) Wageningen University and Research Center, the Netherlands (USD 242,500)[8] (Bothwell, 2016).

From our analysis, universities are considered key agents of social and development change, but have considerable catching up to do in Africa. Arocena and Sutz (2005) present the changing role of universities in Latin America from teaching and research entities to entities including in their mission the introduction of economic development. The 'third mission' for universities was articulated by The Scinnovent Centre. Its framework emphasizes the social dimension of universities, framed as the need to increase their social relevance and impact.[9] The ongoing debate indicates that this societal mission of the university is closely linked to its ability to interact with the private sector in its quest for commercialization and building prototypes. This speaks to the importance of a conducive enabling environment, supported by policies that stimulate innovation and development (Etzkowitz & Leydesdorff, 2000).

Third, the coordinative capacity for information exchange is usually weak or even non-existent in developing countries compared to advanced economies. In the latter, knowledge and

[8] Income figures are adjusted for purchasing power parity.
[9] http://thirdmissionframework.scinnovent.org.

information flows are relatively better in the public domain, and actors tend to have greater access to such flows, except in cases where trade secrets are involved.

Finally, there are significant differences in the regulatory regimes and functions of systems when one compares advanced and emerging nations. Advanced economies have built enduring and strong institutions that have persisted over long periods of time to drive vehicles like PPPs in R&I relatively smoothly. Most African countries have only a few, weak regulatory institutions, especially those that have to cope with rapidly evolving new technologies and complex science systems.

Equally important from a systems perspective are three identified analytical points of entry: (i) the enabling environment, (ii) the organizational level, and (iii) the individual level (Connolly & York, 2002; UNDP, 2009). These three points are linked and complemented by two additional entry dimensions: (i) partnerships and (ii) communities (Vallejo & Wehn, 2016). The enabling environment consists of policies, legislation, regulations, power relations, social norms, coordination bodies and information systems, as well as economic, cultural and informal institutions, and norms and standards (Lincklaen Arriens & Wehn de Montalvo, 2013; UNDP, 2009).[10] The organizational level includes government agencies, policies, teams and their routines, procedures, frameworks and knowledge management. It also includes the private and corporate sector, civil society organizations and the incentive system (Lincklaen Arriens & Wehn de Montalvo, 2013). The individual level embodies knowledge, skills, experience and attitudes (UNDP, 2009). It involves not only individuals in decision-making positions, but also project and team leaders, as well as emerging leaders, advisers, coaches, mentors and trainers (Lincklaen Arriens & Wehn de Montalvo, 2013). This level also includes large amounts of inter-personal interdependence (Voeten & Parto, 2006).

However, fostering innovation involves taking certain explicit and deliberate steps, starting with an inventory of factors that can influence the adoption of innovation, such as: (i) ensuring the supply of organizational resources (including capacity) and infrastructure; (ii) promoting the culture and environment for innovation; (iii) engendering leadership and management; and (iv) putting in place a framework for institutional decision-making. Undoubtedly there will be barriers and bottlenecks that arise and there may be capacity and institutional hiatuses at different levels of the system. These will be consistent with the behavior associated with institutions that have to evolve and adapt to different configurations and environments.

In sum, systems of innovation exhibit significant diversity and considerable heterogeneity when we compare countries in Africa with more advanced economies, and we should equally

[10] For more on the enabling environment, see OECD (2011).

expect variations in the interpretation of the concept of, and practices involved in, PPP. We note that the evolution and development of institutions differs between those with market and non-market origins, with the latter providing the leverage for policy intervention at different levels of the economy (Metcalfe, 1997). Clearly, PPPs in R&I in every environment will be driven by institutions, and performance will depend on relative institutional capacities.

5.3 Patterns of interaction

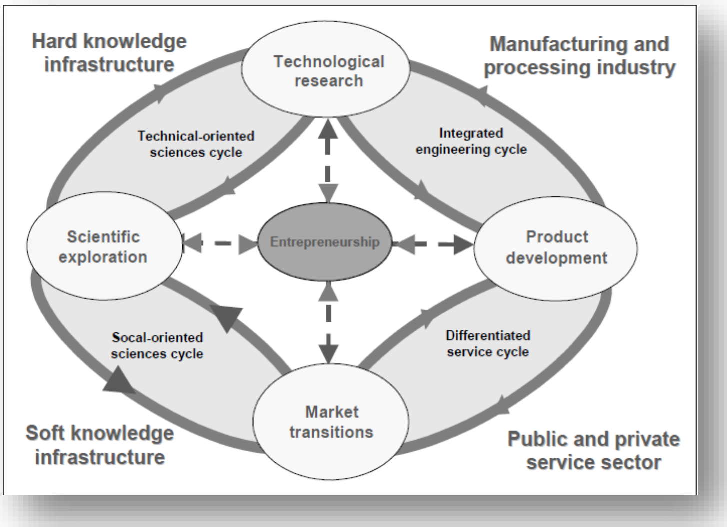
Although the literature emphasizes the need to move from a linear conceptualization of the innovation process[11] to a more iterative and flexible process, in which market signals and information technology are constant inputs (Niosi 1999, Russel et al., 1991), the linear perspective is still very much applied in practice, even though the adoption levels of applications resulting from these schemes is low, at around 30%. Research from the late 1990s shows how interactions, feedback (Hipp, 1999; den Hertog, 2000), and user-producer interactions (Freeman and Lundvall, 1988) play a key role in innovation. The third-generation innovation models highlight the role of investment as part of the strategy of firms and combine technology-push with market-pull strategies, as well as open R&D and a strong emphasis on chain management (Ortt & Smits, 2006). The relevance of feedback linkages in the non-linear process of innovation draws attention to the full scope of the innovation cycle, particularly to the demand side of innovation. Nevertheless, it has been argued that these models emphasize product and process innovations that are typically of a technical nature, while neglecting organizational and market innovations (which are typically non-technical), as well as solutions for institutional barriers and societal needs (Berkhout et al., 2006).

Globalization has brought about different business models with elements of intra- and inter-firm boundaries, resulting in a more complex business environment. This multicultural and multidisciplinary environment requires new innovation directions and combinations. The inadequacy of traditional models, as well as the increasingly complex roles assigned to actors in the innovation system, have radically changed the boundaries of demand and supply in innovation dynamics. They put neither scientific research nor the market first in a sequence of activities; instead, they are built on the idea that "innovation builds on innovation" (Berkhout et al., 2006) and on partnerships and interactions between science and business. These new global-local landscapes for innovation have prompted analysts to search for new ways of explaining innovation, such as the cyclic innovation model.

[11] The linear conception of the innovation process for products, processes and services, consisting of sequential processes that begin with R&D and scientific research and end up with commercial applications (Berkhout, Hartmann, van der Duin, & Ortt, 2006).

The cyclic innovation model is a methodological framework presenting the processes in innovation within cycles of continuous change. The cyclic innovation model places strong emphasis on the relevance of interactions between science and business, on complementary types of knowledge (of technologies as well as emerging markets), on skills for managing networks and interactions, and on the fact that entrepreneurs play a central role in this dynamic (Berkhout et al., 2006; Chesbrough, 2003; Christensen & Raynor, 2003; Niosi, 1999). The cyclic innovation model recognizes the embeddedness of innovation in partnerships (open innovation), as well as the relevance of networks and the concept of the circular economy. Figure 2 presents the cyclical architecture of the cyclic innovation model, which is characterized by interconnected cycles and processes that contain feedback paths through which quick adjustments and learning enhance a very dynamic system (Berkhout et al., 2006; Ortt & Smits, 2006).

Figure 2. The cyclic innovation model



Source: Berkhout et al. (2006, p. 301)

As highlighted by The Scinnovent Centre (2015), the establishment of formal partnerships between universities or other science system actors with the private sector may be the mechanism that empowers this mission and favors national innovation and learning. However, the link between science system actors' knowledge and expertise and the private sector is not natural or automatic (Arocena & Sutz, 2005; The Scinnovent Centre, 2015). It requires an explicit effort and a legal environment that enables this linkage to occur. Therein lies the relevance of the public sphere (i.e., ST&I entities) in providing this framework, as well as tools such as research contracts and PPPs in R&I to endorse it. Table 4 presents a comparison of the different generations of innovation models and their main elements, focus and criticisms, as well as their relationship with the adoption of PPPs in R&I, as tools for helping to dynamically link science system actors with private and public sector actors.

Table 4. Comparison of different generations of innovation models

Generation of innovation model	Main elements	Focus	Criticisms	Relationship with PPPs in R&I
First generation (1G)	- Innovation as a linear sequence of processes - Technology push (linear process with markets at the end of the pipeline)	- Scientific research that ends up with commercial applications	- No strategic goals, no chain management	- Innovation (R&D) within the firm - Universities as providers of basic sciences and human capital
Second generation (2G)	- Market pull (linear process with science at the end of the pipeline) - Innovation as a linear sequence of processes - Contract research	- Market-driven improvements of existing products (optimization)	- Weak ties with corporate strategy - Little emphasis on chain management	- Contractual arrangements for specific knowledge needs - Intra-firm collaborative agreements
Third generation (3G), open R&D model	- Product and process innovation (technical) - Technology push and market pull	- Strong emphasis on chain management - Focus on firms' technological capabilities	- Emphasis is not on organizational or market innovations (non-technical) - Focus is not on including solutions for institutional barriers and societal needs	- Integration of science system actors - Strategic alliances, strategic acquisitions and internationalization of ownership
Fourth generation (4G), open innovation, cyclic innovation model	- Innovation embedded in partnerships - Entrepreneurship plays a central role - Includes feedback paths that allow adaptive steering and learning processes to be more explicit	- Early interaction between science and business - Science push and function pull - Need for new organizational concepts - Skills for managing networks are emphasized - Focus is on processes of change, not on equilibrium processes		- Intra-firm and inter-firm integration and networking - Closer relationships with suppliers and customers - Pre-competitive research consortia - Partnerships
Source: Based on from Vallejo and Wehn (2017) with insights from Rothwell (1992)				

5.4 Other frameworks supporting PPPs in R&I

Although most of the experiences in the field of PPPs in R&I tend to be anecdotal, authors like Koschatzky (2017) present initiatives for theoretical frameworks to analyze these type of interactions. Table 5 presents the main elements used by Koschatzky (2017) to analyze this type of partnership.

Table 5. Theoretical basis for the analysis of PPPs in R&I

Theoretical basis	Basic principles	Knowledge creation processes	Challenges / motivation structure	Key concepts
Transaction costs theories	Coordination Control Governance Regulation	Hierarchical and market coordination Cost efficiency (i.e., external solutions)	Trust Opportunistic behavior	Absorptive capacity
Innovation framework	Dissemination Open innovation Interactive processes Uncertainty	Knowledge inflows and outflows for interactive value creation R&D activities	Creation of new markets	Open innovation Intellectual property
Economic geography	Geographical proximity Social proximity	Confidentiality (exchange of newly-generated knowledge) Face-to-face interactions	Regional attractiveness	Open innovation partnerships
Source: From Koschatzky (2017, p. 7)				

6 International experiences in PPPs in R&I

In Annex 2: Case studies

Table 9, we draw from the literature to present a comparative analysis of PPPs in R&I from different regions. Although the cases span different regions, some conclusions can be drawn. We found that many of the PPPs in R&I in developing countries address issues within the agricultural and health sectors. This reflects similar findings to the study conducted by (African Technology Policy Studies Network (ATPS) & The Scinnovent Centre, 2017), which found that agriculture and health receive the most resources in the SSA region, although this may be changing. Fundamentally, international organizations, donors and development aid agencies are key technical and funding partners in PPPs in R&I (see Annex 2: Case studies

Table 9). Universities are also major players in these arrangements. On the side of the government, we find that government agencies and regional authorities whose mandates do not explicitly cover science, technology and innovation collaborate with other actors to pursue projects in research and innovation to solve key problems in their geographical areas. For example, the Export Promotion Agency of Costa Rica (PROCOMER), is a public agency that partnered with different business entrepreneurs and universities to create a value chain, which improved employment in less developed regions of the country.

Another notable and similar finding is that most of the PPPs were based on formal, not informal, contracts. We can then assume that partners roles and responsibilities within the PPP were always clearly spelt out. Governance arrangements, however, tended to differ depending on the type of project. Even within projects like Bioinnovate, which were implemented across various countries, there were differences in governance, depending on the various government actors.

The following section presents the main national initiatives for PPPs in R&I at the European level, to compare the formalization and execution of such arrangements with those in SSA. The section is complemented by the Indian experience and a case-study of a PPP in R&I between the USA and SSA.

6.1 The European experience

The establishment of the European Research Area in 2000 set the path of the EU research policy and the design of FP6 (2002) and FP7 (2006). Gradually, the instruments used in the FPs evolved and diversified. Public-public and public-private partnerships complemented the grants for transnational cooperative research projects. The establishment of the European Research Council (ERC) and the European Institute for Innovation and Technology (EIT)[12] were complemented by the design of instruments to support SMEs and grants for individual mobility. By 2013, when FP8, called Horizon 2020, was established, the European research landscape had already been redesigned (Reillon, 2017a).

Two things are different under this new paradigm. First, there is a new European approach to economic growth, in which pre-competitive technological discovery and ownership (i.e., through the corresponding patents) are sought as a means to achieve societal challenges that are targeted explicitly in Horizon 2020 and supported by the network of EU regulations and policies. Second, the financial and environmental stimulus towards the development of new industries, such as robotics and activities within the Factories of the Future working programme (e.g., 3D printing, artificial intelligence, green materials and cleaner energies), has initiated the development of these new sectors, whose outputs are expected to be integrated with the existing ones in the near future.

In other words, Europe is moving towards new forms of joint competition in which industries are rising to meet societal challenges – and PPPs are the key element of competition. The competition for FP7 and Horizon 2020 grants brought to Europe the need for intra-regional, intra-sectoral and multi-disciplinary collaboration. Therefore, firms and industries are losing their

[12] The European Institute of Innovation and Technology (EIT) Knowledge and Innovation Communities (KIC) are dynamic partnerships[12] between universities, research centres and business firms carrying out activities along the innovation chain, going from research to the market, and seeking to (i) develop innovative products and services, (ii) train new generations of entrepreneurs and (iii) promote new starters in the business sector. The EIT sets up educational, entrepreneurial and innovation strategies and guides the process, and the KICs are in charge of the implementation and the results. The activities include training, educational programmes, innovation projects, business incubators and business accelerators. Currently there are six KICs, each of them addressing one different societal challenge, covering areas such as climate change, health, sustainable energy, ICT, raw materials and food innovation and production (European Institute of Innovation & Technology, 2017).

identity as manufacturers to become part of the societal needs debate. European economic growth is no longer pursued by promoting individual industries and competing based on costs; instead, the new approach is characterized by competition based on collaborating industries seeking to satisfy societal needs and resulting in the creation of new markets.

Under this framework, and strongly influenced by the American Industry-Universities Cooperative Research Centers programme, the European Commission has promoted several PPPs in R&I. These initiatives are part of the improvement of existing innovation policies and build on earlier initiatives in PPPs in R&I, such as the Joint Technology Initiatives (JTIs) and the EIT's Knowledge and Innovation Communities (KICs)[13], which entered the stage in the late 2000s.

The COMET programme in Austria, the Research Campus in Germany, and the Top Sectors Policy in the Netherlands are examples of how new policy instruments and new PPPs in R&I practices come together virtually and physically. These high-investment PPPs in R&I are examples of publicly-organized efforts, including higher ends of experimental development (called technological readiness levels in the European Commission vernacular).

Austria – COMET

The Austrian national programme, known as Competence Centers for Excellent Technologies (COMET), which started in 2006, is one of the most successful technology policy initiatives in Austria, recognized worldwide for its best-practice model. Its strategic objectives are to build up new competencies by initiating and supporting long-term research cooperation between science and industry and to develop and secure the technology leadership of companies (Koschatzky et al., 2015). The characteristics of the COMET programme are a high level of trust between science and industry, long-term commitment between science and commercial actors, openness to the international environment, and a thematic agenda that is open and not based on predetermined topics.

Germany – Research Campus

In 2011, the German Ministry of Education and Research implemented the Research Campus programme seeking to strengthen medium and long-term cooperation in the interphase between science and business to unlock, bundle and exploit research results. This is the most ambitious initiative of the German federal government to foster the regional engagement of universities in innovation activities. Each Research Campus (currently there are 9 of them) is funded for EUR 1

[13] EIT's mission is to boost innovation in Europe, to promote growth and job creation, and to train the entrepreneurs of the future.

to 2 million per year over a period of 15 years. This amount is complemented by an equal amount from private partners. The pre-existence of a culture of cooperation between knowledge organizations and industry, as well as experience with previous existing contracts and trust among the major actors in the project, favors the establishment of this type of partnership. As the Research Campus is still an experiment based on expectations, so there is not much empirical evidence for its analysis. It is still not known how open innovation processes will be handled when the outputs are more realistic and market implementation and intellectual property rights become issues (Koschatzky, 2017).

The Netherlands – Top Sectors Policy

The Netherlands has nine top innovative sectors, namely: horticulture and propagation materials, agri-food, water, life sciences and health, chemicals, high tech, energy, logistics and creative industries. The government, private sector, and universities and research centres are working together in the Top Sector Alliance for Knowledge and Innovation (TKI) to make these top sectors strong and competitive worldwide. The alliance explores ways to get innovative products or services into the market. Through the Innovative Future fund, the government makes money available to SMEs for research and innovation. The initial capital of the fund is EUR 200 million (2015–2020), from which every year EUR 5 million is made available. The Netherlands Organization for Scientific Research (NWO) contributes EUR 275 million annually to the top sectors, of which more than EUR 1,000 million is for PPPs between university scientists and business sectors. The topics are linked to the societal issues identified under Europe 2020.[14] The contribution of NWO is built on three pillars: (i) PPP1: public-private partnerships (joint programming, with a private contribution required); (ii) PPP2: public-private programming (joint programming, without a private contribution required); and (iii) curiosity-driven research, aimed at the top sectors for which various NWO instruments can be deployed, such as talent programmes.

6.2 The Indian experience[15]

The Government of India's Department of Science & Technology formed the Technology, Information, Forecasting and Assessment Council (TIFAC) as a knowledge networking institution to promote key technological innovation in the country. TIFAC's main objective is to facilitate SME-led technology development efforts early in the innovation chain. TIFAC has conceptualized

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[14] https://www.nwo.nl/en/policies/top+sectors

[15] http://www.tifac.org.in/index.php?option=com_content&view=article&id=563:effective-public-private-partnership-for-innovation-an-indian-experience-&catid=85:publications&Itemid=569

projects of great national importance, such as home grown technology, and bio-products, promoting PPPs to generate market-driven projects. Among the various models that TIFAC adopted, the most successful for technological development was the industry-centric model. This model focused on creating tri-partite agreements between an industry implementing partner from the private sector, a knowledge partner (usually publicly-funded research labs or academic institutions), and TIFAC itself as a facilitator that also provided soft development finance.

TIFAC achieved great success under this model, as most of its projects were concluded successfully, with the final products reaching and satisfying the users. TIFAC recognizes that this industry-centric model proved beneficial, because it serves as an attractive financial assistance scheme, enables technological risk sharing between partners, and enables easy market penetration. The involvement of knowledge partners also proved beneficial, as it facilitated knowledge-based project monitoring by academic and scientific experts. However, some challenges emerged, which provided lessons learnt and led to the creation of best practices for the future. TIFAC's major challenge came under its Advanced Composite Program, in which it noticed that some of the products devolved under the PPP umbrella started being directly substituted for conventional materials. However, the partnering industries and projects slowly gravitated back to the technologies and products whose market success was predictable. Another major fall-out recorded by TIFAC's industry-centric PPP programme was a decline in the number of projects catering to novel and highly technical and innovative applications, reducing the innovation component of the initiative.

This case suggests, as a lesson learnt, that perhaps it would be more beneficial to carry out the first stage of technological development in the national research labs/academic institutes and have it funded purely by the public sector from the government or on a grant-in-aid basis. The industry partner could be brought in as an outsourcing company for the contracting of individual activities, such as process up-scaling or prototyping, etc. on a need basis. At a later stage, when the technology has been developed, the industry partner could then become a fully involved partner, taking on responsibilities such as product testing, manufacturing and other commercialization activities. TICAF also noted that not all innovation development projects springing from national research labs and academic institutes turn into financially-viable products, and some may only serve as knowledge creation.

6.3 The US/African experience: BD-PEPFAR[16]

In 2003, the US President's Emergency Plan for AIDS Relief (PEPFAR) was launched. One of the purposes of the initiative was to address the prevention, care, and treatment of the human immunodeficiency virus (HIV). It became clear, however, that inadequate laboratory services and systems were impeding the scaling up of the programme.

In 2007, a PPP was developed between the Office of the US Global AIDS Coordinator, Centers for Disease Control and Prevention (CDC) and a private global medical technology company, Becton, Dickinson and Company (BD) to support laboratory system strengthening projects in Africa. Identified projects had to be aligned with the goals of PEPFAR and the ministries of health in African countries for the treatment and prevention of HIV/AIDs in Africa. Five countries – Ethiopia, Kenya, Mozambique, South Africa and Uganda – were selected for this intervention based on their political willingness and readiness to provide leadership in the partnership.

The project was implemented at an estimated shared cost of USD 18 million, representing dollars spent, products provided, and time and services donated. The CDC, as the public partner, contributed its expertise in disease detection and prevention, patient monitoring and surveillance. The private agency, BD, identified and deployed BD Global Health Fellows from its worldwide workforce of experts to support local staff in the intervention countries. Between 2008 and 2012 a total of 75 fellows from a wide range of fields, including microbiologists, medical technicians, quality consultants, phlebotomists and logistics coordinators were deployed. Experts from both BD and the International Laboratory Branch within the Division of Global HIV/AIDS (which served as the implementing agency for the project within the CDC) met twice a year for inter-country coordination, strategic planning and technical assistance.

The PPP was successful in delivering on its key objectives, including driving continuous quality improvements in laboratories, providing scalable and measurable outcomes to strengthen national capacities for building technical skills, and supporting evidence-based health programming. Specifically, the PPP was instrumental in reducing the turnaround time for returning laboratory results to physicians and patients. In Addis Ababa, the PPP reduced the time for the collection of antiretroviral treatment specimens to delivery of results by 71%, from 7 days to 2 days. In Mozambique, the PPP supported the Ministry of Health in appointing dedicated personnel to lead the execution of new quality assurance efforts, thus reducing audit costs and reliance on foreign laboratory professionals. The success of the PPP also inspired the partners to develop a series of other collaborations, such as the BD-PEPFAR Safer Blood Collection Partnership,

[16] https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4817354/

implemented in Kyrgyzstan, Kenya, Tanzania and Zambia, as well as another laboratory partnership, Labs for Life, which ran from 2012 to 2017, with support USD 20 million in funding.

The BD-PEPFAR partnership showed the importance and benefits of working collaboratively to innovatively solve some of the world's greatest health challenges, in this case the prevention and treatment of HIV/AIDS. The PPP took key steps to overcome the operational and procedural challenges of working with diverse actors, from different countries, organizations and cultures.

Drawing on the BD-PEPFAR PPP, Shrivastava, Gadde, and Nkengasong (2016) proposed seven steps for a successful PPP using the acronym FOCUSED: (i) F – frame clear goals, roles and responsibilities for partners; (ii) O – operate with open and frequent communication to build trust; (iii) C – communicate conflicts of interest in early stages of engagement; (iv) U – utilize the strengths of other organizations to enrich the PPP; (v) S – share best practices and foster country ownership to ensure sustainability; (vi) E – evaluate and 'measure what matters' using an outcomes-based approach; and (vii) D – deploy the right human resources; people make all the difference.

7 The role of SGCs and the characteristics of PPPs in R&I in SSA.

In the African context, research partnerships and PPPs in R&I are taken as interchangeable and commonly understood as similar concepts as partnerships for development (Oyelaran-Oyeyinka, 2005). While in practice there are different actors, not all are significant at the same time and at all times. In the conception of most policy makers, the main knowledge centres are universities and research organizations; in fact, these are erroneously seen as the sole source of innovation. The role of firms and the potential contribution of public and private design and engineering organizations are hardly factored into the policy process. Although it is true that an increasing number of African universities are making efforts to institutionalize linkages with the private (productive) sector by incorporating different varieties of outreach offices in their structure (see Table 8 in the Annex 1), not all of them have built strong capacities, particularly regarding the management of intellectual property rights, entrepreneurialism and market studies (Ssebuwufu et al., 2012).

Contrary to what conventional wisdom and popular indicators suggest, this knowledge domain for scientific research employs only about 10–12 % of science and engineering manpower in the most research-intensive country, the USA. According to the US National Research Foundation (2016), R&D performed in the United States totaled USD 456.1 billion in 2013. However, the business sector continued to provide the lion's share of R&D performance and R&D funding in the US. For example, the sector performed USD 322.5 billion of R&D in 2013, or 71% of the US total, drawing on business, federal, and other sources of R&D funding. The business sector itself provided USD 297.3 billion of funding for R&D in 2013, or 65% of the US total, most of which supported R&D performed by business. The academic sector was the second-largest performer of US R&D, accounting for USD 64.7 billion in 2013, or about 14% of the national total. The federal government was the second-largest funder of US R&D, accounting for an estimated USD 121.8 billion, or 27% of US total R&D performance in 2013. While most basic research in the US is conducted at universities and colleges through federal government funding, the largest share of US R&D is development, which is mainly carried out by the business sector. The private/business sector also performs the majority of applied research. In 2013, basic research was about 18% (USD 80.5 billion) of total US R&D performance, applied research was about 20% (USD 90.6 billion), and development was about 63% (USD 285 billion).

The above is instructive in understanding the expected role of SGCs in an African context, which is far from the US environment in terms of scientific and technological capabilities. The core function of universities in the US is basic research, but the bulk of the equivalent SGC is the federal government, which funding is only 18% of the total federal funds, while the bulk of R&D is applied and development, which is funded by private firms, constituting over 80% of the total.

8 Domains of knowledge and innovation systems

The case-studies presented in Annex 2: Case studies

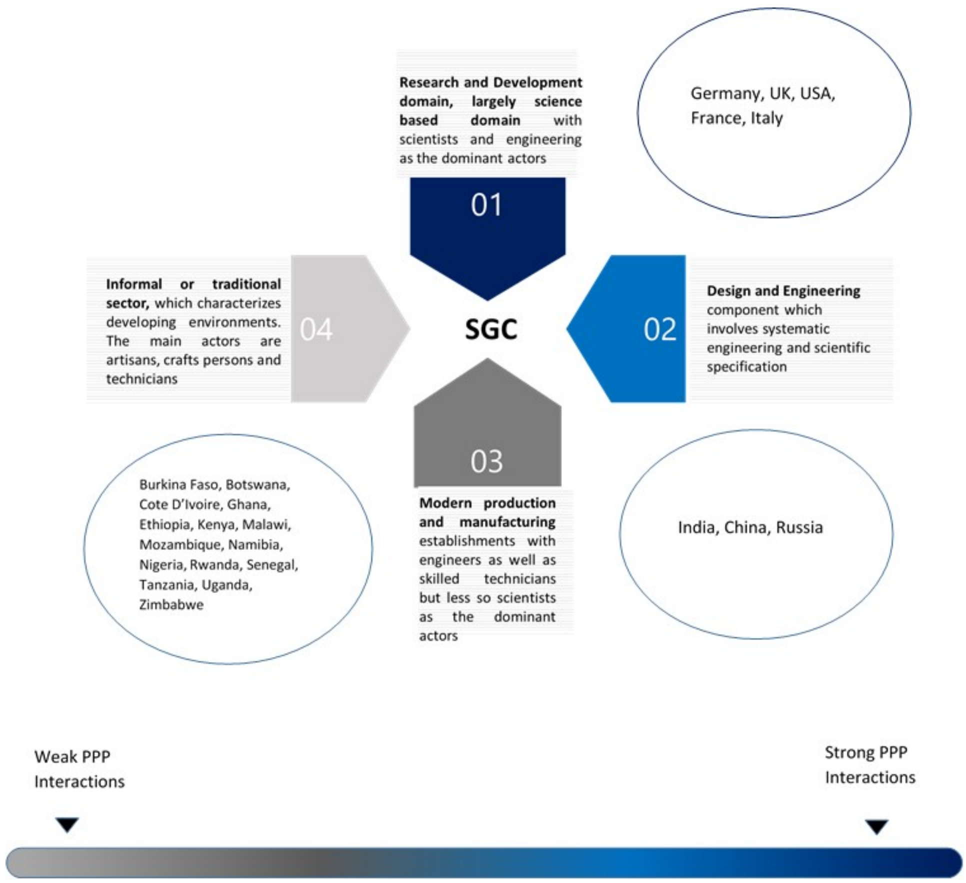
Table 9 (Annex 2) are analyzed within the framework of **Error! Reference source not found.**, which articulates the four different domains of knowledge that SGCs can potentially interact with and intervene in. These four functional dimensions of knowledge are found in both advanced and developing countries. The first domain relates to activities focusing specifically on systematic work related to new knowledge creation. This is a largely science-based domain with scientists and engineering R&D as the dominant activity and research scientists and engineers working in these private and government research laboratories as the main actors.

The second domain is the design and engineering domain. This component involves systematic engineering and the scientific specification of products, processes, and systems, including computer hardware and software. This component is linked more directly to component three, which is the manufacturing and production component, rather than R&D, although outputs of applied research and development feed into this sub-system.

The third domain is the modern production and manufacturing establishments, with engineers as well as skilled technicians, but less so scientists, as the dominant actors. The locus of activity here is the factory and manufacturing centres.

The fourth knowledge domain is the informal or traditional sector, which characterizes developing environments. The main actors are artisans, crafts persons and technicians. The locus of activity is the diverse, but structurally homogeneous, including maintenance and repair garages, clusters of low technology, and traditional products and production processes such as indigenous knitwear, leather and footwear making. The mode of knowledge is largely skill-based tacit and experiential. There are three characteristics of this knowledge base. First, the actors are largely low-level skilled workers and apply low-level technologies based on a mix of modern and traditional methods to manufacture. Second, it is largely disconnected from component three (modern manufacturing and production), although it is not unusual for it to draw on raw materials, such as scrap metals, for instance, which manufacturing rejects, as inputs. Third, its disembodied (human) knowledge is equally disconnected from formal educational centres and laboratories although it is a large part of the economies of developing countries.

Figure 2. SGCs and domains of knowledge for intervention



Source: Adapted from Oyelaran-Oyeyinka and Gehl Sampath (2010)

8.1 Main bottlenecks in interactions between SGCs and system actors

From the interviews conducted and the information presented in Table 8 (Annex 1), it is clear that although most universities have an outreach office, the majority focus on facilitating the administrative tasks needed to support partnerships with international donors. As already indicated by Ssebuwufu et al. (2012), our research also found that very few of the universities analyzed have experience in incubation and science and technological parks.

There is broad agreement among all key actors on the need for SGCs to strengthen relationships with the private sector through formal contractual partnerships, although, contrary to what applies in advanced industrial countries (see US case mentioned above, for instance), interaction is motivated more by potential revenue generation. This is consistent with the findings of Ssebuwufu et al. (2012) in their research on universities in 35 African countries.

The PPPs in R&I in the African context, documented through several case studies, highlight the urgent need to improve the enabling environment to strengthen these desirable types of cooperation. The case studies also point out significant and persistent constraints on performance, such as the inability of local institutions to provide the legal, financial and administrative framework needed for them to succeed (Akampurira, Root, & Shakantu, 2009). Our discussions with SGCs and universities contacted for this research indicate a lack of clarity or lack of formal guidelines regarding the formation of PPPs in R&I. Issues such as corruption (Lilley, 2003; The World Bank, 2005; Williams & Ghanadan, 2006), long administrative processes (Ranjit & Kazim, 2003), and political interference (Sader, 2000) were also documented in several of the case studies in SSA.

Poor institutional settings and the inability of local institutions to provide a healthy environment to enable PPPs in R&I are commonly identified in the literature as factors that constrain private participation in the African context (Akampurira et al., 2009; Kajimo-Shakantu, Kavela, & Shakantu, 2014). Otieno and Obamba (2013) highlight that although Ghana, Kenya and Uganda have development policy frameworks and programme initiatives interconnecting ST&I, the level of coherence between the existing policies, programmes and institutions (i.e., the enabling environment) is relatively weak. Table 6 summarizes the main bottlenecks constraining PPPs in R&I in SSA identified in the literature, complemented by the output of our research.

Table 6. Main bottlenecks/constraints identified by case studies in the literature

Administrative constraints	Financial constraints	External factors	Implementation
Many requirements to obtain project approval	Inability of local institutions to provide equity financing	Resistance from environmental groups	Low level of skills

Lengthy project approval process /lengthy bureaucratic procedures	Poor creditworthiness of loan taker	Resistance from civil society organizations	Lack of proper legislation
Poor coordination between government offices	Investors' concerns about need for intensive managerial resources	Public resentment	Legislation regarding intellectual property is not clear
Political interference in procurement process	Restrictions on return on investment	Corruption	Lack of trust between university and private sector
Lack of (or weak) enabling legal and regulatory framework	Investors' concerns about foreign exchange risks		
Slow implementation of public reforms	Poor access to financing mechanisms		
Corruption			
Lack of or weak political will and support			
Failure of government to honor its contract obligations			
Foreign ownership restrictions (legal framework)			
Openness in the process of the arrangement			
Length of the bureaucratic process			
Source: Compiled from Akampurira et al. (2009); Kajimo-Shakantu et al. (2014) and online survey inputs			

8.2 Governance perceptions of the SGCs and system actors

Table 7 presents the perceptions of three types of science systems actors, namely, ministries/councils related to ST&I (e.g., education, industries or ST&I), public national universities and national research foundations or national research programme agencies. The results are based on the responses of the Science Granting Councils Initiative's main state-owned universities' outreach centre directors.

From Table 7, we can identify clear divergences among the actors regarding the main function of PPPs in R&I. While for the universities and national research foundations/programmes, PPPs in R&I address issues related to market failures (such as the integration and strengthening of the value chain for a local producer, as well as the development of SMEs), for the ministries they produce lessons that should be used in the development of effective ST&I policies. They also act as bridges in the production of knowledge and its exchange between universities and the private sector.

Table 7. The main function of PPPs in R&I for different actors

Entity	Main objective of PPPs in R&I	Initiates and leads the discussions	Main participants from the private sector

ST&I related ministry	To produce research and evidence-based policies	To support knowledge creation and exchange with the private sector	The university or research centre	Large (multinational) firms
Public university	To strengthen the value chain for a local product	To integrate and develop SMEs into a global value chain	The university or research centre	SMEs
National research agencies	To strengthen the value chain for a local product		The public sector	Large (multinational) firms
Source: Online survey analysis				

The interviews with national universities revealed that although the objectives of the implementation of PPPs in R&I are oriented to solve a market failure, mostly related to value chains, the reasoning behind actively looking for these type of partnerships is the large amounts of external revenue that they bring to their centres and to the university. In some cases, it was mentioned that these types of associations are a way for the university to compensate for national budget cuts. [17]

From the discussions, the SGCs, mainly the national ST&I agencies, believe that while large firms are involved in other types of partnership, the directors of outreach centres are mostly focused on partnering with SMEs in the region. As in the case of Europe, close proximity seems to be an important condition for engaging in a formal partnership with the university.

The survey results indicate that on average it is the university that initiates and leads the discussions regarding the implementation of PPPs in R&I. From the interviews, it was clear that universities do not have a structured strategy for approaching the private sector. As presented in Table 8 (Annex 1), the private sector is mainly approached through conferences (where research findings are presented), industrial internships and grant writing. From our conversations with directors of outreach centres, we found that they frequently call industry associations or email local SMEs (whose information is given by the industry registers). These efforts are supported by visits from the university staff to the firms and small meetings in which the university promotes its services and tries to create a culture of trust with the private sector. In the case of South Africa, for example, the main means of communication for grants and partnership opportunities is through the portal of the National Research Foundation and its emails to the grants support offices of South African universities.[18]

[17] Karara, A., personal communication, November 4th, 2017.

[18] Personal communication with lead researchers of PPPs in R&I projects.

8.3 Funding and monitoring mechanisms

As already documented by Ssebuwufu et al. (2012), the incorporation of linkage or outreach offices at national universities has increased in recent years. However, on many occasions, the budget allocated by the university to these offices is meagre and their few staff members do not always have the appropriate set of expertise or skills (Ssebuwufu et al., 2012). This finding is supported by the earlier work of Bolo, Awino, and Odongo (2017) on Kenya.

From the information provided by researchers and directors of the outreach offices, clearly when a partnership is established between a university and the private sector, it is the latter that funds the intervention. The interviews also revealed that the establishment of these partnerships requires intensive valorization efforts by the university, which constantly address the national industry chambers or councils, as well as business registers. The interviewers agreed that the existing business (and academic) culture does not naturally embrace these associations. Therefore, a great amount of explicit effort in fomenting this cultural change is required, mostly due to the nature of the local private sector in these countries, which is formed mainly by SMEs with no R&D&I budget or activities. Once these associations are complete, it is mostly the private sector that finances interventions.

When directly asked, most of the actors, including the universities, recognized the inherent instability of collaborations with the private sector, which are often subject to changes in individual staff members. Furthermore, once a relationship is built, members of the research staff often engage in private consultancies with the private sector that exclude the university. Many of the collaborations with the local private sector are products of person-to-person informal recommendations; on many occasions the request arrives directly to the researcher and not to the linkage office, which may imply a loss for the university.

During the interviews, and supported by our portal analysis, it was mentioned that the main source of funding for the universities (through the linkage offices) is international NGOs and donors, such as the Swedish International Development Cooperation Agency (SIDA), United States Agency for International Development (USAID), the Department for International Development (DFID), and Nuffic (the Dutch organization for internationalization in education), among others. On the university side, and as presented in Table 8 (Annex 1), grant writing has become a strategic tool to compete for external funds. From our conversations with key informants in these donor groups, we found that the fields of applied research or problems targeted by their grants are determined in their headquarters based on (i) the donor country's areas of interest, (ii) the donor funders' areas of interest, and (iii) inputs provided by their embassies in the recipient countries in their assessment of country needs. Gradually, there have been evolving guidelines. For example, grants guidelines are now subject to eligibility conditions involving partnerships between a foreign entity (university, research centre or private sector), a local science system actor and a local community (where the implementation takes place). Most of these grants cover projects of three to five years and require the partnership to be formalized by a memorandum of understanding (MoU) or collaboration agreement, not necessarily a formal contract. The multidisciplinary and multi-institutional strategy is also found in the National Commission for Science Technology and Innovation (NACOSTI)/National Research Foundation framework described by Kenya Engineer (2017).[19] Under the University Research Chairs Programme of NACOSTI, the inclusion of the private sector and a demonstrated demand for the research are compulsory requirements.

8.4 Intellectual property rights and related items

Although from the information provided in Table 8 (Annex 1) we can see the important presence of intellectual property rights and patent offices at universities, this is not yet a strong area of expertise in many of organizations. Not all universities have a clear and firm intellectual property rights policy. In many cases it was reported that the researcher owns the patents and trademarks. The registration of patents is made at the national level.

8.5 SGCs and their linkages with universities

From the analysis of the cases found in the literature (presented in Annex 2: Case studies Table 9, Annex 2), as well as from the survey and the direct interviews with the universities, we found that the role of SGCs and related agencies is often not explicitly recognized. From the interviews, the perception of the universities is that SGCs are largely rule-setting and regulation-making entities: that these agencies provide a legal framework, enforce mandates and create an environment for the establishment of PPPs in R&I. However, when asked about the role of SGCs in project implementation there was no clear delineation of roles.

In line with Mouton et al. (2014) and Bolo, Osir, Rugutt, and Desai (2015), we found that in countries like Kenya and Ghana SGCs are more proactive. It seems that although these organizations have been established in all of the sample countries, their budget differs greatly and, consequently, they have limited capability to actively engage in direct financing of PPPs in R&I activities. Nevertheless, we need to recognize that the provision and promotion of frameworks in which these PPPs could prosper is already a major input. At this stage, out findings are in line with

[19] http://www.kenyaengineer.co.ke/2016-05-28-20-43-28/latest-news/item/360-the-university-research-chairs-programme-call-for-proposals-technological-innovation-in-the-manufacturing-sector

those of Otieno and Obamba (2013), who stated that the integration of higher education institutions in these countries is not consequent on the knowledge-based development discourse off the authorities.

8.6 Regional participation of SGCs in PPPs in R&I in SSA

The SGCs are not visible in many of the activities in the case studies presented in Annex 2: Case studies

Table 9 (Annex2), although we recognize that a different set of case studies may very well deliver a different narrative. We found that, in the literature, cases in which the SGCs are active partners in PPPs in R&I are scarce. In Annex 2: Case studies

Table 9, the majority of cases involve industry-university engagement, and less with private industrial firms. From the interviews and the findings of Ssebuwufu et al. (2012), it is clear that international development agencies are fundamental players in funding R&I efforts in SSA.

In Annex 3: Funding mechanisms for SGCs

Table 10 (Annex) we present in comparative tabulation the different mechanisms implemented globally by SGCs to fund a wide variety of industry-science system actor partnerships in order to compare their platforms of interaction, areas of attention and monitoring mechanisms. From the table it is clear that interactions through websites, national (mostly annual) meetings and email communications are well established. Although there are pre-discussions on the establishment of priority areas, these are in line with national or regional pre-established strategic points. The most successful mechanism for the promotion of PPPs in R&I has been through grants for five to seven-year projects.

9 Discussion of findings

In SSA SGCs are mainly government ministries, departments and agencies, which are involved in different interactive functions. They interact with a wide variety of actors, including public and international research institutions; university departments; private firms (both local and foreign); and international research institutions. The adoption of PPPs in R&I enables costs and risks to be distributed among the system actors, facilitates the integration of new knowledge into an industry, and, most importantly, fosters collaboration with firms by providing them with consulting and expertise at an affordable cost. Regarding the promotion of ST&I, our discussion with key actors indicates that it is largely done under the umbrella of ministries for ST&I, SGCs or ST&I councils. However, there are countries in which ST&I promotion is done by the ministry of industry or the ministry of economy, representing the government in these affairs.

9.1 Knowledge centres and motives for partnership

To understand the key agents and motives of PPPs in R&I in Africa, we needed to find answers to two questions in our interviews: Firstly, who initiates the PPP process – is it the university, the firm or another entity? And, secondly, what form of formal or informal contract guides the process? In the advanced industrialized nations that we studied, two broad types of formal contract are common, namely: academic entrepreneurship contracts and spin-off companies from public research or universities.[20] These are uncommon in many African countries, because university professors are unable (due to capacity constraints) or disinclined to pursue commercial ventures. Relatedly, the cost in time and money to pursue such a line of activity is too high and, therefore, acts as a disincentive, giving rise to institutional arrangements such as outreach offices.

In contrast, firms in advanced industrialized nations tend to seek partnerships with universities and grant councils for a number of reasons. Firstly, firms and other organizations are incentivized to pursue external knowledge to share risks and costs, due to the growing complexity of knowledge search and production. This is because the nature of knowledge generation is complex, demanding a high level of scientific skills often found in universities. Second, autonomous efforts are costly and innovation outcomes generally uncertain; through partnerships with universities and grant councils, firms are able to share the risks and spread the costs. In the African context, universities take the lead for different reasons, one of which is that PPPs increase the possible sources of public and private funding. They also help facilitate technology transfer and human training activities. In our study, the main actors in PPPs in R&I identified universities as the major players. For this reason, an increasing number of African universities are making efforts to institutionalize linkages with the private (productive) sector by incorporating outreach offices in their structure, however, most are poorly-equipped and few have the capacity to deal with the most urgent challenges in the society.[21] For example, our research also found that very few of the universities interviewed have experience in incubation and science and technological parks.

The interviews with the national universities revealed that although the objectives of the implementation of PPPs in R&I are oriented to solve a market failure, mostly related to value chains, the reason for actively looking for these types of partnerships is the large amounts of external revenue that they bring to their centres and to the university. As mentioned previously,

[20] Academic entrepreneurship takes several forms, namely: (i) involvement in large-scale externally-funded research, (ii) consultancies to earn supplementary income; (iii) university-industry research and transfer of technology, (iv) patents and trade secrets, and (v) commercialisation, which might involve holding equity in private enterprises by scientists, see Altonen (1998).

[21] This finding confirms that of Ssebuwufu et al. (2012).

these partnership are also a way for universities to compensate for national budget cuts.[22] From our fieldwork, it is evident that while most universities have established an outreach office, they tend to focus on rudimentary functions such as facilitating administrative tasks needed to support partnerships with international donors, rather than with national SGCs (see Table 8, Annex 1). The directors of outreach centres tend to work mostly with SMEs.

Regarding the adoption of PPPs in R&I, we found a direct relationship between SSA universities and the private sector when an international NGO or donor is involved (mostly SIDA, USAID, IDRC, DFID). When an SGC is involved, the relationship is not always straightforward. This is consistent with the findings of Mouton et al. (2014) in their analysis of SGCs in SSA in 2014. Most of the interviewees recognized the Ministry of ST&I as a proxy for SGCs as a provider of legislation and enabler of the environment for PPPs in R&I to come into effect.

As with the non-African case studies that we studied, close proximity seems to be an important factor for engaging in formal partnerships with African universities. Our survey results indicate that it is mainly the university that initiates the implementation of PPPs in R&I. However, universities do not have a structured strategy for approaching the private sector. The platforms used for engaging the private sector include conferences where research findings are presented, industrial internships, grant writing, phone conversations with industry associations, and emails to local SMEs, among other things. From the observations in discussion groups, it is evident that it is the private sector that funds PPPs and usually initiates the contact with the university. On many occasions contact is based on person-to-person communication between the firm and a particular researcher at the university. Universities also conduct advocacy missions addressed to associations to promote their services, although on rare occasions they need to sub-contract experts to address the problems brought by the private sector. Although PPPs are generally formalized in signed documents, the trust by the private sector in the university is not strong and much work needs to be done in this regard (trust can be enhanced by visits by the university staff to the firms and meetings in which the university promotes its services and tries to create a culture of trust with the private sector). In South Africa, the main means of communication about grants and partnership opportunities was through the National Research Foundation and the grants support offices of South African universities.[23]

[22] Karara, A., personal communication, 4 November 2017.
[23] Personal communication with lead researchers of PPPs in R&I projects.

9.2 The private sector

According to the SGCs members in Africa interviewed, the private sector is mostly composed of small firms engaged in retail trade and low-level services, with a very narrow manufacturing base. We know from the literature that firms and organizations are considered the main driving force behind technological change and innovation; they influence the nature and type of financial support for adopting new technologies and the firm's ability to successfully adapt products and processes (Oyelaran-Oyeyinka & Lal, 2006). Except for in the largest economies in Africa, the private sector is generally composed of SMEs. Several studies (Lal, 2002; Lall, 1982) have found a positive relationship between a firms' size of operation and the level of its innovative activities, including its propensity to collaborate. Larger firms tend to possess the human resources required to establish and sustain lateral relational interactions, while small firms look more to the state, including SGCs, as well as to professional associations, for support. Larger firms are also generally more innovative in modifying product specifications, due to greater resources (knowledge and skills). Evidently, the size of African enterprises constrains their ability to partner with other system actors (such as universities) and with other firms.[24] Oyelaran-Oyeyinka and Kaushalesh (2016) highlight how the service sector has taken the conventional position of industrial manufacturing in Africa in the process of structural transformation. This might well be one of the reasons why progress in PPPs in R&I that leads to an innovation-driven knowledge economy in Africa has been slow – because the region has basically 'skipped' the industrial phase and is moving directly into low-productivity service sectors, such as finance, transportation, trade and low-level ICT sub-sectors, in the process of structural transformation. Structural transformation is the transition of an economy from low-productivity and labor-intensive economic activities (i.e., agriculture and low-skilled services) to higher productivity and skill and innovation-intensive activities (Oyelaran-Oyeyinka & Kaushalesh, 2016). The driving force behind structural transformation is the growth of innovation-induced productivity in modern sectors, which is dominated by manufacturing and services; manufacturing in many countries in Africa contributes little to overall GDP, the domain where PPPs should be most active.

9.3 Sector focus

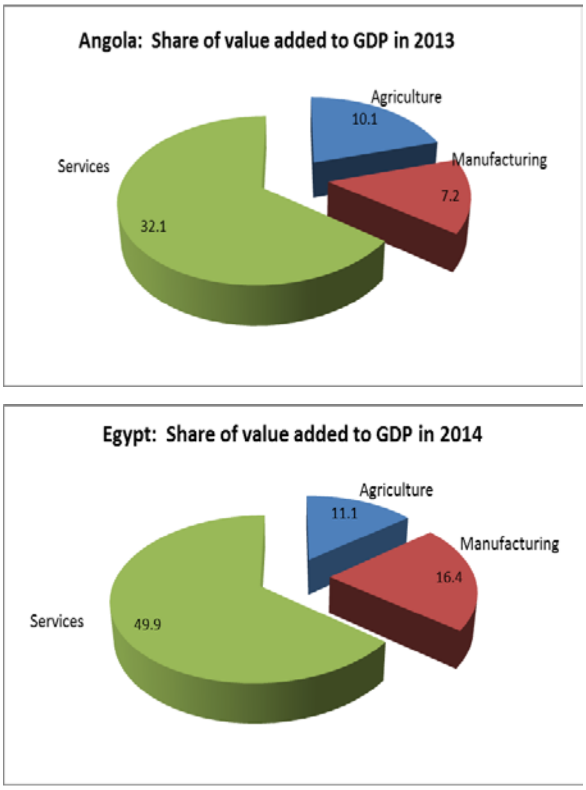
According to SGCs, most PPPs in R&I in developing countries address issues in the agriculture, food, water and health sectors. This reflects findings similar to those of the African Technology Policy Studies Network (ATPS) and The Scinnovent Centre (2017), who found that agriculture

[24] Thamae. L., personal communication, 23 November 2017; Njapau, H. and Chinkusu, J.M., personal communication, 23 November 2017.

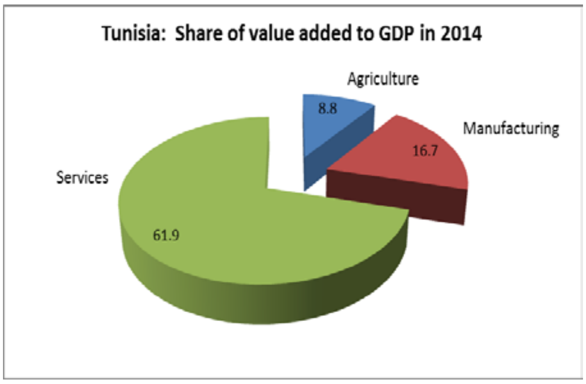
and health receive the most resources in the SSA region. One suggestion that resonated constantly in conversations with the SGCs is the imperative to harness local funds for R&I in sectors of national interest.[25] The sectors repeatedly mentioned were agribusiness, food processing, seeds, and vaccinations.

The driving force behind structural transformation is the growth of innovation-induced productivity in modern sectors, which is dominated by manufacturing and services. Structural change is equally attended by the movement of the workforce from labor intensive activities to skill-intensive urban-based ones. However, economic growth in African countries, including all the countries in this study, is being driven not by innovation-led manufacturing that fosters PPPs in R&I, but in low-productivity services (see Figure 3).

Figure 3. Service-led growth in SSA countries



[25] Ndilila, F., Thamae. L., Dia Tine, S., and Zeinebore, O. personal communications, 23 November 2017.



Source: From Oyelaran-Oyeyinka and Kaushalesh (2016)

The issue of property rights was also addressed mostly by universities. Offices with expertise in patents and idea registration are already well established in almost all universities. When the partnership involves funds from a public entity (i.e., government), the property right or patent remains within the university. However, when the funds come from a private entity, particularly an international organization, then the property right or the patent goes to the private entity.

An important issue identified is that in the North this tool is being used as a strategy to promote and strengthen state-of-the-art technologies, seeking to maintain leadership at the technological frontier (and ownership of the technology through patents and intellectual property rights) and addressing pre-established societal challenges. Meanwhile, the South is using the tool as an instrument to build or strengthen its industrial base, integrate its SMEs into the global value chain, and create employment.

10 Conclusions and policy recommendations

SGCs are central to the long-term development of ST&I-led development and will continue to play a key role in the successful evolution of different forms of PPPs in SSA. However, our findings bring us to several conclusions and recommendations for academics, various actors within state systems of innovation, and policy makers in SSA.

Recommendation 1. Strengthen systemic cooperation and learning

SGCs are in a position to facilitate specific research agenda as a tool for systemic cooperation and learning. SSA's private sector is quantitatively small, and its science and knowledge system relatively weak, both financially and institutionally. Private SMEs tend to engage in atomistic and uncooperative behavior, because of their struggle to deal with daily routines, including non-available public goods, which are taken for granted in advanced societies. These small actors also lack information search capabilities. They need support and to interact with universities to raise their collective productivity. This must be facilitated by instruments of policy, as it will not happen spontaneously. Therefore, it is recommend that SGCs in Africa engage in the deliberate creation of capacity strengthening for sectoral interaction mapping and learning, as in European initiatives. Both the inter-disciplinary nature of the scientific and knowledge base, as well as the complex processes involved in bringing products from laboratories to firms make a range of knowledge interactions critical to competence building at the sectoral level, including engaging with, promoting, and monitoring and evaluating the knowledge interactions between a variety of different key actors (such as university departments, centres of excellence and public research institutes; traditional knowledge holders [farming communities] and other more research-based and product development actors; local and foreign firms and universities; local and foreign firms; local and foreign firms; farmers, consumers, seed banks and other intermediary organizations that help gauge local demand and issues imminent to the agricultural system; various governmental agencies responsible for promoting these competencies locally).[26] Such knowledge interactions are difficult to measure, but can be gauged using a combination of factors, such as: the percentage of funds devoted to research; the percentage of research contracted to and from outside organizations; the level of joint research with other organizations (basic, applied or product development initiatives); the number of scientific publications jointly written with other institutions; the level of co-authorship based on joint research; the exchange of key technical and scientific personnel (numbers and levels of qualification); the involvement in joint R&D programmes organized by the government at the sectoral level; and the amount of consultancy research carried out for other organizations, both local and foreign.

Recommendation 2. Strengthen state institutions for PPPs in R&I

In the developing African environment, research and development institutions and their relationships with firms are weak and ineffectual, despite progress over the last decade with the establishment of organizations and institutions that regulate and coordinate innovation functions. State institutions for PPPs in R&I need to be strengthened to enable them to use PPPs for R&I as strategies for advancing technological change in Africa, in addition to addressing market failures. Therefore, in line with Oyelaran-Oyeyinka (2004b), we suggest that developing African countries approach the task of developing their national system of innovation with vigor and devote resources to key sectors.

[26] www.iadb.org

Recommendation 3. Support policy-induced partnership

Policy-induced partnerships need to be supported. Our study confirms the significance of network partnerships in promoting innovation in both European initiatives and successful cases in Africa and other regions. PPPs in R&I work to generate inter-agent collaborations. However, this cooperative interaction between economic agents in advanced economies responded largely to inducement tools and mechanisms. In Africa, as in other places, collaboration will not happen naturally and policy inducements and facilitative incentives need to be applied consistently over time.

Recommendation 4. Strengthen the governance of systems of innovation

Finally, the governance of national systems of innovation needs to be strengthened. In addition to weak scientific bureaucratic capacity, there is a general consensus from the findings that fiscal limitations pose serious challenges and set limits on what is possible in research, innovation and technology development in SSA. Overcoming these challenges will require a carefully coordinated approach, which recognizes the need to balance prudent fiscal policy with initiatives aimed at encouraging the private sector to invest substantially in innovation. Frameworks to promote linkages between universities, science, engineering and technology institutions, and the private sector are required to share risks (using partnership innovations). The findings call attention to the severe internal challenges inherent in the STI governance structure generally and the PPP in R&I specifically, as well as the existing lop-sidedness of the STI administrative system.

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Annex 1: Research platforms

Table 8. University-industry research platforms

Country	University	Name of outreach department	Research department/office	Outreach platforms	Local donors	International donors(main)	Activities with local private sector	Patents and intellectual property rights, copyrights and trademarks
Botswana	University of Botswana	Office of Research and Development Incubation Centre	Office of Research and Development Research Commercialization Unit Okavango Research Institute	Grant writing Visits to industry to promote the use of licences for inventions made by the university	Government	African universities Development NGOs		Research Commercialization Unit For the university
Burkina-Faso	Universite de Ouagadougou	La Direction de la Cooperation inter-Universtaire	Scientific Council	Grant writing Conferences	Government	European Union, World Bank, African Development Bank, FIDA, Belgium/Danish/ Canadian/German /Norwegian development cooperation, Bill and Melinda Gates Foundation (USA), Ecobank Group (Togo), Ford Foundation (USA), McArthur Foundation (USA), OXFAM	Through international projects – mainly in health and agriculture sectors Community level	
Cote d'Ivoire	Félix Houphouët-Boigny University (Abidjan)							
Ethiopia	Addis Ababa University	University-Industry Linkage & Technology Office Technology Business Incubation and	Technology Business Incubation Centre (AAU-TBIC)	Grant writing Visits to companies Consultancy agreements Industrial internships	Local industry Government		Improvement of product quality Improvement of production processes Development of new products	Mostly kept by the university

		S&T Park (planned)		Professional conferences Faculty personal contacts Publications			Industrial internships	
Ghana								
Kenya								
Malawi	University of Malawi							
Mozambique								
Namibia	University of Namibia	University Central Consultancy Bureau	Centre for Research and Publications	Short training courses for non-scholars and ministries Grant writing	Internal funds from the university		Consultancies (i.e., business plans, impact assessments, product development, market analysis, policy design) Training Technical ICT Training	
Rwanda*	University of Rwanda	Office of Resources Mobilization	College Directorate of Research, Innovation and Post-Graduate Studies (DRIPG) Research Unit	Annual conference with current and potential donors Grant writing/ management Approaching companies and charitable foundations Sponsorship Internships	Government (47%) Internally generated (19%)	Swedish Cooperation, Blekinge Institute of Technology, DIKO, AUSaid, UN Habitat, Nuffic, ESRI, McArthur Foundation (USA), SIDA (Sweden), Rockefeller Foundation (USA), University of Liege (Belgium), Global Fund (USA), USAID, European Union	Training of local staff for the private sector Provision of services for the private sector	Mostly kept by the university

				Conferences Publications MoUs				
Senegal	Cheik Anta Diop University (Dakar)	Direction de la Cooperation	Technological Park (planned)		African universities	Several European universities, Iranian and Russian universities, American, Canadian and Brazilian universities		Mostly kept by the university
Tanzania								
Uganda	Makerere University	Each college engages in its own collaboration and partnerships	Directorate of Research and Graduate Training Food Technology and Business Incubation Center – CAES Centre for Research in Energy and Energy Conservation – CEDAT Centre for Tobacco Control in Africa – CHS Microsoft Innovation Center – CoCIS Petroleum Exploration and Production Technology Laboratory – CoNAS	Grant writing	Government of Uganda 1% of university income goes to research (this money is generated from the faculties, contributions from graduate and undergraduate students) Bilateral funds from development partners	SIDA/Department for Research (SAREC) (Sweden), NUFFIC Indian cooperation, USAID, Uganda Gatsby Trust, Rockefeller Foundation, Carnegie Corporation (USA) – African Partnership for Research Excellence (CAPREx), Development Research Uptake in Sub-Sahara Africa (DRUSA), Africa Regional International Staff/Student Exchange (ARISE), Consortium for Advanced Research Training (CARTA), Norwegian Agency for Development Cooperation (NORAD), Research Professional Africa, Next Generation of African Academics (NGAA)	Mounted model villages Arua and Rakai districts	
Zambia	The University of Zambia	International Link Office	Platform for Research, Science, Technology, Innovation and Development (PReSTID)	Dissemination of research findings Meetings with public and private sector to encourage use	National ministries (particularly for health and agriculture)			Mostly kept by the university

				of university research outputs Newsletter				
Zimbabwe	University of Zimbabwe	Each faculty engages in its own collaborations and partnerships	Quality Assurance Office	Conferences Presentation of graduates' research outputs Annual research and intellectual expos	Local industries National ministries (for health, water, land, S&T)	Other national and African universities (e.g., Polytechnic of Namibia, Cape Peninsula University of Technology)		Professors keep a lot of them
Source: Authors' own research based on information from the digital portals of universities and complemented by phone and Skype calls with directors of various outreach offices								

Annex 2: Case studies

Table 9. Analysis of diverse case studies from the literature

Location	Identified need	Description	Product/innovation	Main actors involved	Governance arrangements	Formal/informal contracts	Funding mechanisms	Role of SGCs, if any
San Jose, Costa Rica (ECLAC, 2017)	Creation of employment, integration in value chains of less developed regions	Creation of a value chain	Chain of chips fried in air	Private sector: different business entrepreneurs University: CITA, University de Costa Rica Government: PROCOMER, COMEX	PROCOMER identified the need and pushed for the project	Formal contracts		P
Java, Indonesia (ECLAC, 2017)	Strengthen the access of small agro producers to technologies and extension services, as well as integration with new markets	Creation of space to address development needs of agro business through implementation Different value chain issues are addressed in a practical way	The creation of a value chain centre	Private sector: (agro)business entrepreneurs University: University of Padjadjaran Government: regional authorities and the Ministry of Agriculture		Formal contracts		None
	Environmental (water and soil) pollution Contaminated water and poor sanitation facilitate disease transmission and increase the mortality rate of children under 5 years old	Use of nanotechnology for water and soil clean-up Involves students in R&D, publications and potential patents	Reduction of cost of water purification methods	Canada's International Development Research Centre (IDRC), United States International University-Africa (USIU-Africa), Edith Amuhaya (Kenya), Rhodes University (South Africa), Ottawa University (Canada)	South Africa-Canada Research Chairs	Formal contract (5 years)		

Port Elizabeth, South Africa (Koen, 2016)	Affordable and accurate healthcare Reduction of HIV treatment costs	Testing CD4 cells in blood using a cell-phone camera (capable of reading CD4 counts in HIV positive patients) and a test strip with biomaterials	Development of prototypes for monitoring CD4 counts from blood samples using a cell-phone camera	UNICEF, Rhodes University's Biotechnology Innovation Centre (RUBIC) (South Africa)		Formal contract (ZAR 3 million)		
Ghana (2011–2017)	Ensure technology development and diffusion is more responsive to the needs of the economy	Increase capacity and incentives for research institutes, universities, and technology providers to develop, adapt and diffuse technologies to private sector enterprises on a demand-driven basis	Establishment of offices/centres of technology development, marketing and transfers within institutions	Ministry of Environment, Science Technology and Innovation (MESTI) World Bank Research universities: University of Ghana & Ghana Technology University College Research institutions: Council for Scientific and Industrial Research and Ghana Atomic Energy Commission Polytechnics: Kumasi Polytechnic	MESTI oversees the selection of research bodies and monitors their progress	Formal contract (USD 2.5 million)	Grant (each institution received USD 500,000)	Facilitate collaboration between research bodies and private sector by outlining general project objectives from government's perspective, selecting research bodies, and providing grants
Kenya, Burundi, Ethiopia, Rwanda, Tanzania and Uganda	To support East African countries to leverage the benefits of converting ever advancing bioscience technologies into innovations to foster inclusive growth and	Bioinnovate is essentially a multidisciplinary competitive funding mechanism, for biosciences and product-oriented innovation activities in Eastern Africa It functions as a two-phase programme:	Funding and facilitating the development and innovation of several different bio-based ideas and innovative technologies across East Africa	Donors: SIDA, New Partnership for Africa's Development (NEPAD) Partners: (Depending on the country and project) several universities from East Africa, several universities	Depending on the project and region, various government actors from the respective country/region are involved with other regional and international actors.	Formal contracts for each project	Call for funding is advertised by SIDA, applicants must apply with their relevant project idea and with support from the host organization, which must be willing to match grant funding.	

	sustainable development	Phase I lasted from 2010–2015 and encompassed building innovation consortia/ platforms on crop improvement technologies, the sustainable utilization of agro industrial waste, and bioscience innovation policies and value added products from millet and sorghum. Phase II (2016–2021) is focusing on linking bio-based technologies and ideas to the market and commercializing the ideas/technologies and businesses.		outside the region, various national research institutes (NARIs), three African regional initiatives, international research institutes (IRCs) and different councils/ ministries for science and technology			Applicants can be from any of the participating countries and can often even be a team from the different countries. Funding is then provided for a set period and a budget established through the Biosciences Innovation Fund.	
India	Develop an affordable, safe and effective HIV/AIDS vaccine for India and other developing countries	The PPP was set up to research, develop, patent, test (clinical) and enable the manufacturing of a safe and effective HIV/AIDS vaccine, as mandated by the Indian government, for India as well as neighboring and other developing countries.	HIV/AIDS vaccine	Indian Council of Medical Research (ICMR), the International AIDS Vaccine Initiative (IAVI) (USA), National AIDS Control Organization (NACO/Indian Ministry of Health), and Therion Biologics (USA)	ICMR is responsible for ensuring the proper functioning of the entire project and that it meets its objectives. A project management committee made up of representatives from ICMR and IAVI was also established to manage, coordinate, monitor and assess all project activities.	Agreement signed between ICMR and IAVI Several other contracts signed between the partners for different purposes (e.g., patents and technology transfer agreements etc.)		

Clinical evaluations in India and China	Creating cervical cancer screening tests that are affordable for women in the developing world	PATH formed a partnerships with two private firms to develop the test formats to detect human papillomavirus (HPV) (one using DNA, and the other using a biomarker protein). Both companies will create a safe, accurate and simple to use test	Screening Technologies to Advance Rapid Testing (START) project to develop affordable, safe and accurate cervical cancer screening tests	PATH and two private firms		Formal agreements between PATH and two industry partners and special intellectual property arrangements	Funding to PATH awarded by Bill & Melinda Gates Foundation	
Africa	Lack of an affordable vaccine to treat epidemic meningitis across Africa	PATH and World Health Organization (WHO) worked together with the other partners to develop the low cost vaccine for sale at a price of USD 0.40 per dose across Africa	Affordable, effective group A meningococcal vaccine by the Meningitis Vaccine Project	PATH, WHO PPP between SynCo Bio Partners B.V, Serum Institute of India Limited (SIIL) and the US Food and Drug Administration's (FDA) Center for Biologics Evaluation and Research		Formal agreements and special intellectual property and knowledge transfer agreements	Funding to PATH and WHO awarded by Bill & Melinda Gates Foundation	
	Lack of temperature control for vaccines in developing countries in vaccine cold chain or distribution networks	This project aims at improving vaccine thermo-stability (the inherent ability for vaccines to withstand extreme temperatures) to ensure that every child in the world receives safe and uncompromised vaccines despite the flaws in the cold chain.	Improving vaccine stabilization technology	PATH is working with a wide range of private sector companies and universities.		Formal agreements and special intellectual property and knowledge transfer agreements	Funding to PATH awarded by Bill & Melinda Gates Foundation, plus companies also funded R&D	
Ethiopia, Kenya, Mozambique, South Africa and Uganda	Inadequate laboratory services and systems, that could impede the	To support laboratory system strengthening projects in Africa	Improved laboratory services and systems	Public Agency: Office of the US Global AIDS Coordinator, Centers for Disease		Formal arrangement	Shared cost of USD 18 million between PEPFAR and BD representing	Not observed

	scaling up of the US President's Emergency Plan for AIDS Relief (PEPFAR), aimed at the prevention, care, and treatment of HIV infection			Control and Prevention (CDC) Private sector: Becton, Dickinson and Company (BD) Various government and health care facilities in implementing countries			dollars spent, products provided, and time and services donated	

Annex 3: Funding mechanisms for SGCs

Table 10. Funding mechanisms of different SGCs around the world

Country	Ireland	The Netherlands	Ghana
Ministry of S&T (yes/no)	Yes	Yes	Ministry of Environment, Science Technology and Innovation (MESTI)
SGC proxy	Science Foundation Ireland	The Netherlands Organization for Scientific Research (NWO) – Applied and Engineering Sciences (AES, previously the Technology Foundation, STW)	Ministry of Education
Mandate	To develop world-leading, large-scale research centres linking scientists and engineers in partnerships across academia and industry	Knowledge transfer between the technical sciences and users so as to emphasize the role of users in all AES projects	
Objectives	In line with agenda Europe 2020	In line with agenda Europe 2020	
(a)	To develop new and existing Irish-based technology companies	To answer demand-driven questions from the industry with the open submission of research ideas from the university or research centres	To facilitate collaboration between research bodies and the private sector by outlining general project objectives from the government's perspective, selecting research bodies, and providing grants
(b)	To contribute to the Irish economy	To promote consortia and partnerships between industry and academia	To increase the capacity of, and incentives for, research institutes, universities, and technology providers to develop, adapt and diffuse technologies to private sector enterprises on a demand-driven basis
(c)	To expand educational and career opportunities in science and engineering		
National policies supporting the mandate	- Intellectual property management guidelines - National policy statement on ensuring research integrity in Ireland.	Top sectors agenda of the Dutch government	
Ethical and scientific issues	Regulated by clearly established policy documents and guidelines	- In line with the intellectual property policy adopted by NWO 'Rules of Play for public-private collaboration', as presented to the Lower House of the Dutch Parliament on 25 June 2013 - Also offers knowledge institutions the opportunity to make their own intellectual property and publication	

		arrangements with the parties with whom they wish to cooperate (in this way they can better respond to the wishes of the researchers and co-funders involved in the research projects)	
Matching funds by industry	Required in most applications related to research centres, CSET and SRCs	In-kind contributions required	
Budget	EUR 355 million (from government) + EUR 190 million (from industry)	About EUR 57 million of AES's budget comes NWO and the Ministry of Education, Culture and Science, EUR 23 million from the Ministry for Economic Affairs, EUR 17 million from third parties and EUR 14 million from cash co-financing by companies participating in research projects. In addition to this the partners make in-kind contributions to the research.	World Bank is the main funder
Number of centres	12 centres		
Number of companies involved	200		
Areas of support	Pre-established on basis of economic and societal needs	Pre-established by the industry based on its needs; includes industrial doctorates (PhDs)	
Areas	Pharma, big data, medical devices, nanotechnology/materials, marine renewable energy, food for health/functional foods, perinatal research, applied geosciences, software, digital content, telecommunications and medical devices	Broad themes previously discussed by Dutch companies and in line with those targeted in Europe 2020	
Mechanisms of communication	Website, email list	Website, email list, annual information meetings	
Source: Elaborated by the authors based on information available on the online portals			

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